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Short Cropping at Pioneer*

By R. M. Allen

Realizing that questionnaires are sometimes a nuisance, the writer has refrained from requesting others to answer numerous questions on the subject of short cropping and has decided to discuss it as it appears to us at Pioneer.

I hope that the problems that we are up against and which will be briefly enumerated in this paper, will invite discussion by those interested and that the subject can be covered more fully than had a chosen few been requested to fill out a lengthy questionnaire.

We have always had "short ratoons". In fact, I think it has always been the custom on most plantations to harvest certain fields in November and December, and harvest these again a year from the following June and July. These so-called "short ratoons" are actually from 16 to 18 months old, just as old, in fact, as many of our so-called "long ratoons". What we are primarily interested in now are the fields harvested between January and May.

At Pioneer the harvesting schedule in general usually called for the fields that were to be short ratooned to come off first, followed by the fields to be planted and harvested two years hence, and lastly the fields to be long ratooned. Our short cropping policies do not affect the first two classes of fields, but have a decided effect on the early harvested fields that would ordinarily be long ratoons. In the past we have given a field harvested in March practically no attention, except sufficient water to keep it alive until June, July, or even as late as August and September. This field would then be harvested in March and April and would apparently be from 24 to 26 months old. Actually, however, considering the fact that it had only been kept alive for from 3 to 6 months after it was cut it was only from 17 to 20 months old. Under our short cropping schedules this same field would be fertilized and irrigated immediately after it was cut, and

* Presented at seventh annual meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 15, 1928.

would continue to get the same intensive treatment that had always been given the old so-called short ratoons and would be harvested again in July or August of the following year, at an actual age of 17 months. By following this practice all of the idle time, which occurred under the old system, has been eliminated and the land involved has been producing continuously. Figuring that our lands are capable of producing say .35 of a ton of sugar per acre per month, an idle period of 4 months, although it may not represent a loss of 1.40 tons of sugar, does result in some definite loss.

From this standpoint the "short cropping" system, or "cut and grow system" or "intensive cropping system" has appealed to us and we have extended materially our area of short ratoons. In order to handle this additional area it is necessary to do one of two things: either add to the labor supply or slow up harvesting. In the writer's opinion this can best be accomplished by slowing up on the harvesting and using the men that would normally be in the harvesting field, in the ratoons. In fact it may be advisable to stop harvesting two or three times during the season and clean up, fertilize and irrigate the ratoon fields. This year at Pioneer we shut down for three weeks in June, and the probabilities are that we will do this twice during the next season: once in March and once in June or July.

The result will be, of course, that we will not finish grinding until late September or even October, in some cases, where we normally would be through by the latter part of June or the first of July. From the field man's standpoint this practice seems sound, and is, I believe, better than adding materially to the labor supply and creating jobs for them during the longer off-season that we used to have when we finished grinding early (June or July). However, before we can be sure we can carry this out year after year we must consult our mill engineers, as it means cutting the off-season available for repair work just about in half, and there is some question whether or not our mills can be reconditioned in this relatively short time. This is an important point to bear in mind when weighing the possibilities of the more intensive system of cropping, and our mill men should have a loud voice in the discussion which is taking place on this subject.

From the standpoint of irrigation, I believe that this system will result in a saving of water, in spite of the fact that there is an added area of small cane to care for during the entire year. This saving will result from the fact that there will always be a smaller area of big cane to irrigate during the dry months of June, July and August than there would have been under the two-year cropping system. Take for example a typical field harvested in April, 1928. Under our old system the schedule would call for the field to be harvested again in February, 1930, at an age of 22 months. Under our intensive cropping system we would plan to harvest it in September, 1929, at an age of 17 months. During the months of June, July and August under the former system we would be irrigating this field full blast in order to take full advantage of the second summer's growth; but as a short ratoon we would begin to ripen it in June and it would receive practically no water during July and August, 1929. The water would then be available for irrigating the young ratoons, and, of course, would serve a much larger acreage than had it been used in the big cane. Whether or not this saving will compensate for the larger acreage under cultivation is an open question.

Here at Pioneer we are up against the additional problem of fluming fields that are short cropped, and consequently harvested late. We have always figured that it was essential to finish fluming these fields before June, at which time our water shortage usually sets in. In our 1928 crop, we had a considerable acreage of short ratoons situated in our flume area, where we are short of water, and did not finish fluming there until August. The theory was when planning the crop that it would not take as much total water to flume these under the new system as it would to irrigate under the old system. We have gotten by with it, but it is necessary to hold off on the conclusions as we got unusually good water.

In considering yields under our short cropping system it is necessary to forget for a time the yield per acre and think in terms of tons of sugar per acre per month, and even this does not tell the entire story. Ten tons of sugar per acre sounds like a good yield (?) and 7 tons is considered a poor yield. However, if the former is from a field growing 24 months and the latter is from a field that has been growing only 17 months, both have produced a yield of .426 ton of sugar per acre per month. Over a period of years a condition such as this favors slightly the long crop, as the short crop has been started out and cut oftener than the long crop. However, a slightly larger yield, of say 8 tons per acre, which I believe is entirely possible in localities where a 10-ton long crop yield is possible, would yield .470 ton of sugar per acre per month and turn the tables in favor of the short crop. In 72 months, or a time equivalent to three long crops, the long crop would have yielded about 31 tons of sugar and the short crop about 34 tons.

All of this is pure theory and although some plantations may have conclusive evidence for or against short cropping, we at Pioneer are still in doubt and are extending the policy largely on the theoretical evidence in favor of it.

The average yield of sugar per acre at Pioneer of long and short ratoons for the past four crops is given in the following table:

	1925 Crop	1926 Crop	1927 Crop	1928 Crop
Long Ratoons........................	7.35	6.65	7.70	8.40
Short Ratoons........................	5.83	7.14	7.03	7.06

It should be explained here that the long ratoons of 1926 suffered considerable strike damage.

A little more light is thrown on the subject when the age of the various fields is considered. The average age and yield in tons of sugar per acre per month for the 1926, 1927 and 1928 crops are shown below:

	1926 Crop		1927 Crop		1928 Crop	
	Age	TS/A/M	Age	TS/A/M	Age	TS/A/M
Long Ratoons................	22.27	.299	22.26	.346	23.66	.355
Short Ratoons................	17.10	.419	18.93	.366	19.31	.366

The average yields in sugar per acre per month for plant, long and short ratoons for the four crops 1925, 1926, 1927 and 1928 are given below:

	Age	TS/A/M
Plant	21.59	.457
Long Ratoon..................................	22.73	.332
Short Ratoon..................................	18.49	.370
Grand Average................................	21.97	.368

There is another point in connection with this problem which should not be overlooked. Increasing the acreage of short ratoons means, of course, that a larger percentage of the total area is harvested each year, and the larger the acreage harvested the smaller the charge per acre for the fixed charges that go to make up the total cost of a crop.

A rough examination of the cost figures on several plantations shows that approximately 30 per cent of the total cost remains the same, regardless of the area harvested. In this 30 per cent is included office, management, taxes, water rent, general repairs, a certain portion of mill expenses, carpenter shop, machine shop, garage expenses and many other items with which we are all familiar. These charges are more or less fixed and remain practically the same whether we harvest, say 2500 acres or 2750 acres per crop. For the sake of argument, say, the total cost of a crop on a given plantation is $1,250,000. Thirty per cent of this is $375,000. On a normal crop of 2500 acres this represents a cost of $150 an acre. If 250 acres of short ratoons have been added and the total area increased to 2750 acres, the cost per acre would have been $136 or a difference of $14 on every acre in the crop. Assume a normal yield of 8 tons of sugar per acre and we see that the cost per ton of sugar would be reduced $1.75 a ton by simply increasing the area harvested.

The fallacy in this argument is, of course, the fact that the average yield would probably be reduced by the additional short ratoon area. Just how much a 10 per cent increase in short ratoon area will decrease the average yield it is too early to say definitely, but it is very probable that it will not be more than .25 of a ton of sugar per acre. If this is true the cost per ton for these fixed charges would in one case be $18.70 a ton, and in the other $17.20 a ton, or a difference of $1.50 a ton of sugar due to a 10 per cent additional area.

There is, of course, reason for argument on this point, but the writer firmly believes that, everything else being equal and discounting a reduction in yield due to the short ratoon area, a 10 per cent increase in area will result in a reduced cost of at least $1.00 a ton of sugar. This is, of course, a very strong argument in favor of the short ratoon theory and it will be interesting to see how the costs on the plantations that have extended their short ratoon area compare with previous years under the old system. It is very possible that by proper treatment many of our short cropped fields can be made to yield very nearly the same as the average yield of our long ratoons, in which event the above argument is strengthened.

The fertilization of our short ratooned fields presents another problem that must be carefully studied. Most of us are of the opinion that the last fertilization should be about a year before harvesting. This means that in the case of a field cut in April the first fertilization is in April or May and the last application of either nitrate of soda or sulphate of ammonia is given in July or August. According to all the growth figures available the rate of growth drops rapidly from this month on and there is some question whether a given amount of fertilizer applied at this time has the same value as the same amount applied in January or February, as would be the case in a long ratooned field.

We have noticed this year that our short cropped fields yellowed off early in the year and there is a possibility that we would have fared better if we had split our last fertilization and applied part of it in December or January, depending on an increased yield to make up for the poorer juices that might have resulted from the later application of fertilizer.

One of the serious problems in short cropping arises from the fact that fertilization in many of the fields must take place prior to or just following the tasseling period. There was a time when we thought a dose of fertilizer in August or September would decrease the amount of tasseling. Our experiences at Pioneer during the last few years have led us to believe that this is not the case. If anything, the contrary is true, and instead of forcing our fields out of tasseling we forced them into tasseling.

The question here is whether it is better to get all the fertilizer on early, within four or five months after the field is cut, and get the full advantage of the early summer's growth that the fields will have, or to spread out our fertilization in an attempt to keep the field growing during the cooler months.

The feeling is strong among those that are giving this matter thought, that the intensive cropping system will enable us to ratoon longer, due to the fact that the vitality of the stools is kept up during the entire life of the crop. Comparing this with the practice we used to follow at Pioneer, of hardly keeping our fields alive for three to six months after they were cut, there is little question but that this treatment weakened the stools and forced us to plant oftener than will be necessary under the new system. It will be fortunate if this proves to be true, for the success of our short cropping practice depends largely on the extra cost of starting the ratoons and harvesting oftener being offset by the ability to ratoon longer.

Summarizing the problem, I feel that there is strong evidence favoring a more intensive system of cropping. We still have a lot to learn as to the best method of handling this increased area, and the point wherein our profitable limit of increased production lies. We know that we can ripen our fields in from fifteen to seventeen months, and can materially increase our total production by extending our short ratoon area. Whether or not this increased production is profitable, remains to be seen, and the real test will come when the cost figures for crops containing this added area are available.

The Residual Effect of Nitrogen Salts Upon Drainage of Heavy Clay Soils

By W. T. McGeorge

In comparing the development of agriculture in humid and arid climates, that is, adequate and insufficient rainfall, longer lived soil fertility has been predominately associated with the former. Where artificial irrigation is practiced a more rapid deterioration of optimum growing environment in the soil takes place. Of

course, in climates where irrigation is necessary climatic conditions are often such as to have greatly changed the chemical nature of the soil, and this being little understood has served to lead the irrigation farmer more rapidly into pitfalls. Failure has on the whole been due to either an excessive saline content of the irrigation water, to a rise in water table from excessive irrigation and poor drainage or to the accumulation of salts from poor drainage alone. Under any one or all of these conditions it is only a matter of time until the salt content of the soil solution exceeds the limit of tolerance of the crop.

We have devoted considerable time and study to the problem of salt accumulation in our plantation lands and have definitely shown a number of cases where salt accumulation has injured and even completely prevented cane growth. On the other hand the physiological effect of salt upon the cane plant is only one phase of the problem and possibly a minor one at that. Changes in the chemical nature of the soil solution, especially where large amounts of soluble salts are involved, may result in an extremely undesirable mechanical condition. The soil may become relatively impermeable to water, difficult to till and often quite unproductive.

This latter phase of the salt or alkali problem has received much intensive study the past few years which has been of infinite profit to the irrigation farmer both in helping him to avoid the pitfalls of irrigation practice as well as to intelligently reclaim his mistakes. Briefly these investigations have shown soils to contain certain silicate compounds, components of clay, known as zeolites, possessing jelly-like properties, which lie at the very foundation of soil behavior, both physical and chemical. The basic character of this clay component largely determines the permeability of a soil, and this basic character is directly governed by the composition of the irrigation water or the nature of the chemical salts used in commercial fertilizers. Permeable or well-drained soils are predominantly lime soils and any practice which results in a disturbance of this condition will usually result disastrously for the farmer. Use of high sodium waters and continuous use of nitrate of soda are known examples. Once the soil reaches a state of low permeability some source of soluble lime is essential for its reclamation. Any reclamation program must needs involve some type of leaching, which, too, must be intelligently planned and followed out. When a soil has once become impermeable, salt water will move through it faster than fresh water. In fact the latter when applied to a saline soil will usually result in a "freezing up" and therefore a lower degree of permeability than formerly existed will follow. A logical procedure, therefore, for reclaiming an impermeable soil is to provide drainage and flood with water, either pump or fresh, to which a soluble lime salt has been added.

Few of our plantation soils are so completely impermeable as to make cropping impossible. On the other hand, we have large areas of heavy clay soils in which water movement is sufficiently poor as to greatly slow up drainage and often injure cane growth. Examination of soils from such areas has usually shown the lime which should predominate to have been in part displaced by other elements, notably, sodium and magnesium or hydrogen, the latter to form an acid soil. Notable accumulations of salt are also often found in these poorly drained areas.

The yields on many such fields are not sufficiently depressed as to warrant any drastic reclamation program which would require the abandonment of cropping for a period. But the question arises as to a plan looking toward a gradual improvement in fertility and drainage by slight modifications in methods of fertilization.

Of the nitrogen, phosphate and potash compounds used in commercial fertilizers the phosphates are usually good flocculants and work for better mechanical condition of the soil. The muriate and sulphate of potash too are not usually given to harmful residual properties. On the other hand, the residual effect of the nitrogen carriers does often notably influence the physical condition of the soil and therefore its ability to "take water." Of course, one logical procedure would be, as already stated, to add soluble calcium salts to the irrigation water if a change in fertilizer is objectionable. This would tend to balance the use of high sodium waters and to restore the calcium balance in the soil, thereby making for better permeability.

The continuous use of sodium nitrate in some arid districts has met with more or less disfavor. This, however, was previous to our knowledge of its effects upon the soil zeolites. Thus far we have no evidence that any such objectionable effect has followed its use here in the Islands. On the other hand, one would most logically suggest certain modifications for applying nitrate of soda to our heavy clay types with a view toward improving the mechanical condition of the soil. While it is definitely certain that substitution of nitrate of lime for nitrate of soda would make for rapid improvement in permeability the property of this material for rapidly absorbing moisture has caused much objection to its use.

The following experiments were conducted to gain information regarding the comparative effect of nitrate of lime, nitrate of soda, ammonium sulphate and potash nitrate upon water movement and to determine if sodium nitrate or potash nitrate fertilization could be modified so as to improve permeability in a heavy clay soil from Field 11, Ewa Plantation Company. A short history of this field may be of interest. Previous to 1920, difficulty had often been experienced in ripening cane on this field on account of a high water table. A system of tile drainage was installed at this time at a depth of four feet in order to lower this water table with a view toward ripening the cane. One result of this drainage system has been to remove large quantities of salt from the soil. On the other hand permeability has been quite variable and notably better cane growth has characterized the better drained spots. In fact, at the beginning of the last ratoon crop a number of poorly drained areas had to be replanted on account of the complete failure of the stubble to survive the environment produced by the poor drainage and salt accumulation. It may be seen, therefore, that this soil was excellently suited to the experiments which we had in mind. It might be mentioned that nitrate of potash was being used as the nitrogen carrier in this field because of the fact that it is deficient in potash.

Experimental

This study involved three series of experiments. The soil was ground to pass a 60-mesh sieve. Soil columns 16 cm. in length—approximately 100 grams of

soil—were prepared as carefully and uniformly as possible in small glass percolators. The soil columns thus prepared were placed under a head of 100 cc. of water for all tests. The rate of water movement was determined by noting the volume of percolate at intermittent periods of time. All solutions of nitrogen salts were made up to contain 5 grams per litre or 0.5 per cent salt.

Series 1: The purpose of the first series was to show the residual effects of the salts when dissolved in salt free water or water containing no other salines. Ten soil columns were used involving a duplicate for each salt, and checks which were leached with water alone. Four leachings of 100 cc. each were made on each column. Following this all columns were placed under an equal head of distilled (salt free) water and the residual effect of the salts on water movement determined.

A salt solution will, with rare exceptions, show a more rapid rate of water movement than pure water through a soil, which held true in this soil. All the salt solutions moved faster through the soil columns than water alone with nitrate of lime showing the highest rate. However, on changing all the columns to a head of pure water they all "froze up" with the exception of the one which had received nitrate of lime, and this continued to permit the water to pass just as rapidly as before. The residual effect is illustrated graphically in Fig. 1, in which rate of percolation is shown by plotting volume against time.

Series 2: It is a matter of common observation in the Islands that the coral fields are usually fields that "take water" well. The question arises as to the effect of supplementing nitrate of soda or other nitrogen salts with coral rock or gypsum. Series 2 was conducted to determine this.

The experimental procedure used was the same as that described in Series 1. Where calcium carbonate or sulphate (gypsum) were added they were placed on the surface of the soil column at the rate of 1 gram per 100 grams of soil, or one per cent the weight of the soil. This series included thirty soil columns or fifteen different treatments in duplicate. Ten columns were repetitions of Series 1; ten had additional applications of calcium carbonate; and ten had applications of gypsum. Distilled water solutions of the salts were used and the columns leached four times with 100 cc. at each leaching. The rate of flow was taken as in Series 1 and then all columns were placed under equal heads of pure water and the residual effect noted. The results are shown graphically in Fig. 3.

In all cases where nitrate of lime was used an excellent rate was maintained. The effect of carbonate and sulphate of lime upon pure water is also of interest. Under calcium carbonate and gypsum in Fig. 3 the solid lines represent the rate of movement for the first application of water following the salt solution, and the dotted lines the second leaching or after the salts had been leached out. In other words, the dotted lines represent the residual effect of the salts.

Series 3: The experiments described in Series 1 and 2 show the residual effects of the salts when dissolved in distilled water. But the residual effect is always notably influenced when other salts are present in the water. For this reason another series of soil columns was prepared and in place of distilled water

plantation pump water was used. Our island waters are often high calcium and magnesium waters which type will usually limit the fixation of other bases in the soil and therefore lessen their residual reaction. The plan of Series 3 was exactly as described in Series 2, except that the nitrogen salts were dissolved in pump water. The residual data from this series is shown graphically in Fig. 4.

It will be noted that the residual effects of the several nitrogen salts are notably different where applied to the soil with pump water. In spite of the fact that the nitrate was applied in amounts somewhat greater than a field application, there is sufficient calcium and magnesium in the pump water to greatly limit the fixation of sodium by the soil. The pump water used was the same as that used on this soil in the field and had the following composition:

Total solids	1258	ppm
Calcium Ca	82	"
Magnesium Mg	79	"
Sodium Na	113	"
Potassium K	6	"
Chlorine Cl	448	"
Sulphate SO_4	97	"

In this series none of the soil columns "froze up" within the time of the experiment, and, with the exception of sodium nitrate, in the presence of calcium carbonate all showed excellent to fair water movement.

Effect on Zeolites

As previously stated, the ability of a soil to take water is largely a function of the nature of the bases combined with the zeolite silicates of the clay fraction. Fortunately, there is a great difference in the affinity which the zeolites have for the various bases, and this affinity is least for sodium as compared to magnesium and calcium, which three are the dominant soluble bases in soils and water. Therefore, a considerable excess of sodium in the soil solution must be present for the fixation of this element to reach injurious proportions. In order to make the preceding experiments more complete the soils from the soil columns were analyzed to determine what the effect of the treatments had been upon the composition of the zeolites. These data are given in the following table and are shown graphically in Figs. 4 to 11:

Fig. 4. Fixation of ammonium from ammonium sulphate has been largely at the expense of the calcium and magnesium, both of which were materially reduced. However, there is nothing in the data to indicate that the soil has suffered any permanent injury, but rather that in an experiment such as this where the ammonium sulphate is not given time to nitrify, a small amount of ammonium zeolite has been formed which on hydrolysis caused a temporary dispersion of the clay.

Fig. 5. Fixation of calcium has taken place almost entirely at the expense of the magnesium. The sodium and potassium already only present in small amounts have not been materially affected.

TABLE SHOWING PER CENT ZEOLITE (REPLACEABLE) BASES IN SOILS FROM SERIES 2 AND 3 LEACHING EXPERIMENT

	Calcium Carbonate					Gypsum					Water				
	Am. Sul.	Cal. Nit.	Sod. Nit.	Pot. Nit.	Water	Am. Sul.	Cal. Nit.	Sod. Nit.	Pot. Nit.	Water	Am. Sul.	Cal. Nit.	Sod. Nit.	Pot. Nit.	Water
Calcium pump	.212	.339	.232	.205	.218	.225	.321	.257	.252	.284	.148	.298	.184	.164	.204
Calcium dist.	.179	.327	.138	.142	.227	.133	.330	.226	.117	.257	.107	.270	.091	.128	.183
Magnesium pump	.054	.062	.090	.072	.115	.047	.040	.063	.042	.074	.062	.050	.105	.081	.119
Magnesium dist.	.028	.018	.046	.034	.096	.020	.023	.049	.031	.069	.040	.020	.046	.060	.100
Potassium pump	.014	.020	.022	.244	.020	.012	.015	.017	.217	.015	.006	.017	.018	.267	.020
Potassium dist.	.012	.021	.030	.347	.023	.013	.024	.031	.328	.036	.015	.034	.021	.377	.027
Sodium pump	.023	.022	.070	.028	.023	.018	.018	.050	.023	.018	.025	.020	.104	.028	.021
Sodium dist.	.026	.023	.062	.034	.024	.017	.019	.048	.029	.021	.019	.011	.083	.027	.017
Ammonium pump	.143					.095					.161				
Ammonium dist.	.152					.164					.190				

Fig. 6. Fixation of sodium from sodium nitrate was largely at the expense of the calcium and magnesium.

Fig. 7. Fixation of potash also was largely brought about by a replacement of calcium and magnesium. The excessive fixation of potash is extremely significant and of more than passing interest. The data indicate that potash is fixed in forms other than as the zeolites, possibly physical absorption.

In Figs. 8, 9, 10 and 11 are shown graphically the advantages of pump water over pure water as a means of retarding fixation of sodium from sodium nitrate. The soils from the soil columns used in Experiments 2 and 3 show in nearly every case that those leached with pump water are higher in calcium and magnesium but lower in sodium and potassium.

Conclusions

These data strongly endorse the use of nitrate of lime as a nitrogen carrier for our heavy clay soils, at least until the mechanical condition of the soil has improved sufficiently to permit average permeability, and that nitrate of soda is the least desirable for such types. Even when applied with calcium carbonate or calcium sulphate, using pump water, drainage is much slower where nitrate of soda is used. In fact, the experiments show little or no advantage in supplementing nitrate of soda with limestone or gypsum. On the other hand, the effect of the limestone and gypsum alone on permeability would make for better drainage between nitrate applications, and therefore a gradual improvement in the mechanical condition of the soil.

The extremely hygroscopic property of nitrate of lime has been the cause of much prejudice against its use. It was for this reason that some knowledge of the effect of lime and gypsum upon the residual properties of nitrate of soda was studied. The conclusion appears inevitable that nitrate of lime is so far superior to the other forms of nitrogen for improving the permeability of heavy clay soils as to favor its extensive adoption on such soil types if improvement in permeability is desired.

On the basis of this same property of nitrate of lime there is probably need for caution against loss of nitrogen by too rapid permeability if it is desired to use this form of nitrogen on well drained soils.

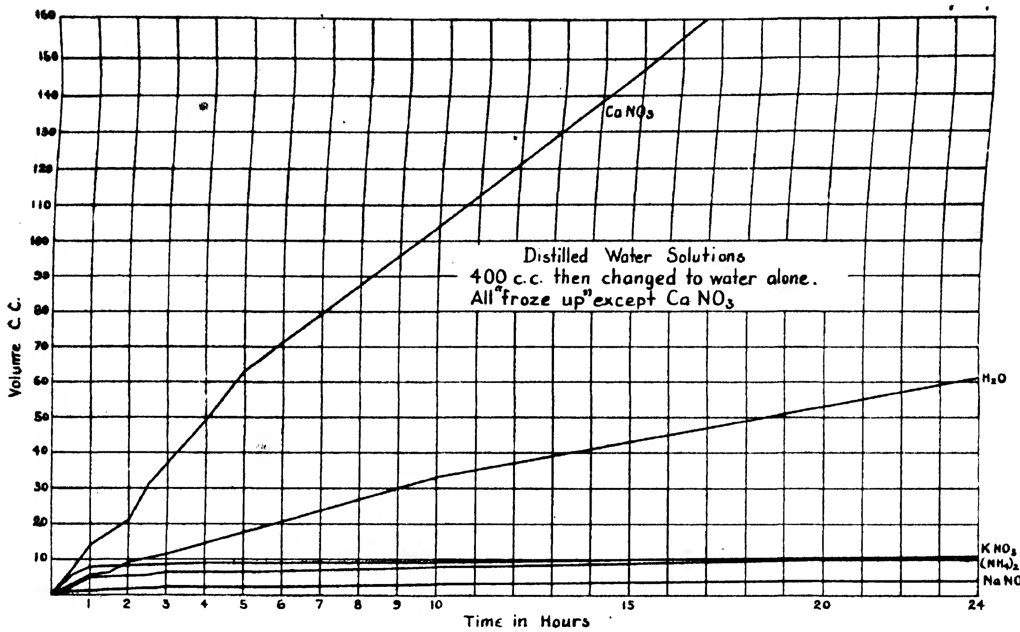

Fig. 1

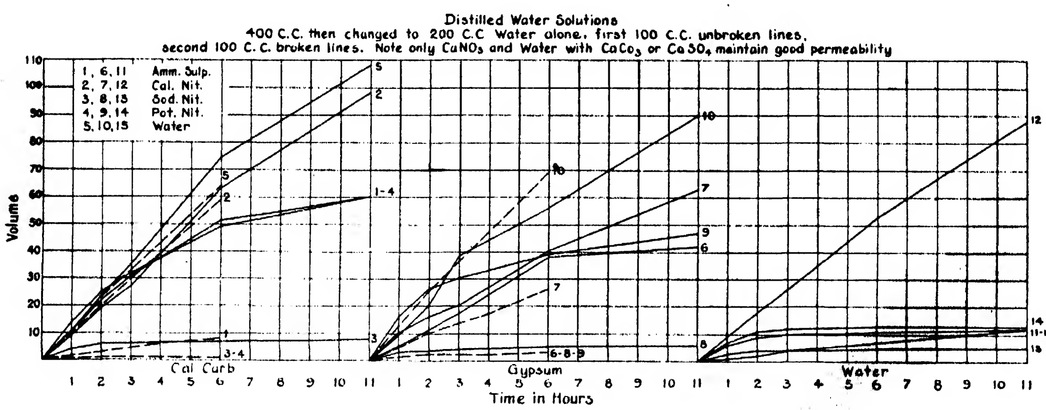

Fig. 2

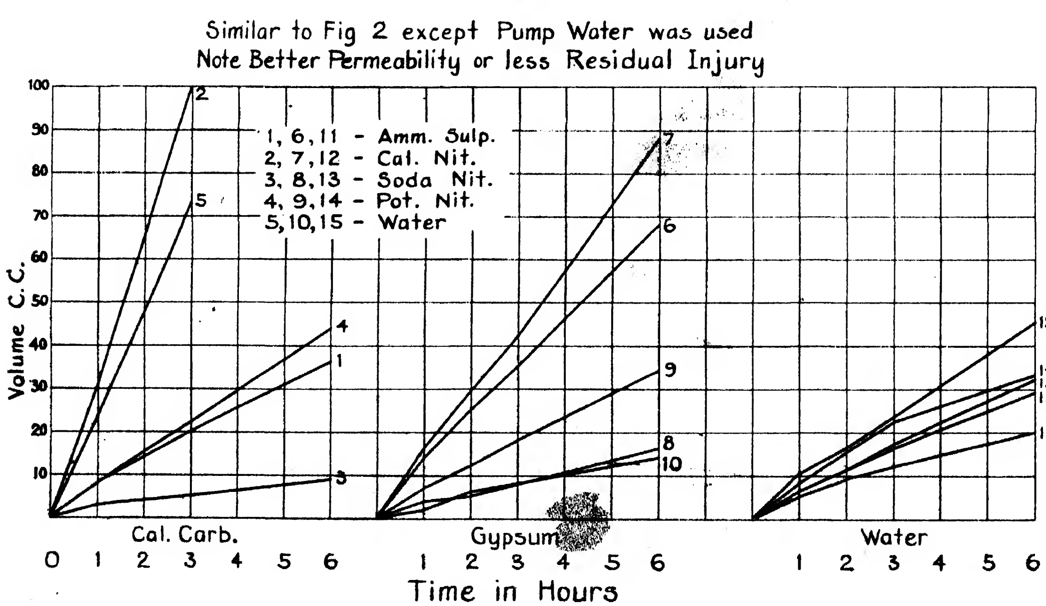

Fig. 3

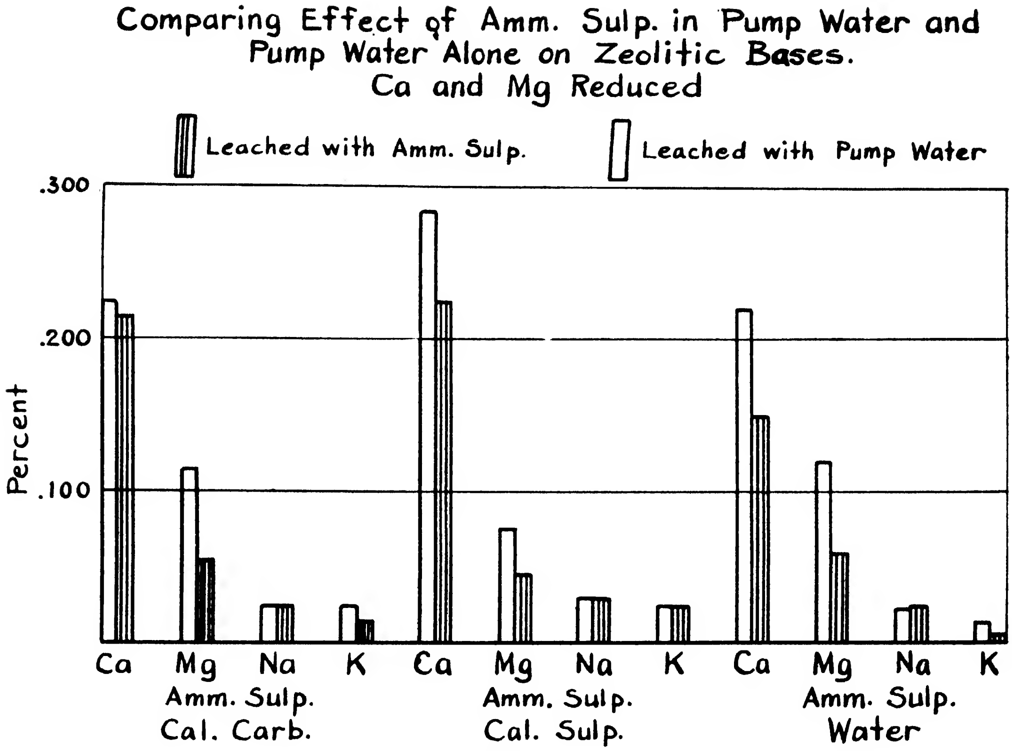
Comparing Effect of Amm. Sulp. in Pump Water and
Pump Water Alone on Zeolitic Bases.
Ca and Mg Reduced
Leached with Amm. Sulp.
Leached with Pump Water
.300
.200
.100
Percent
Ca
Mg
Na
K
Ca
Mg
Na
K
Ca
Mg
Na
K
Amm. Sulp.
Cal. Carb.
Amm. Sulp.
Cal. Sulp.
Amm. Sulp.
Water

Fig. 4

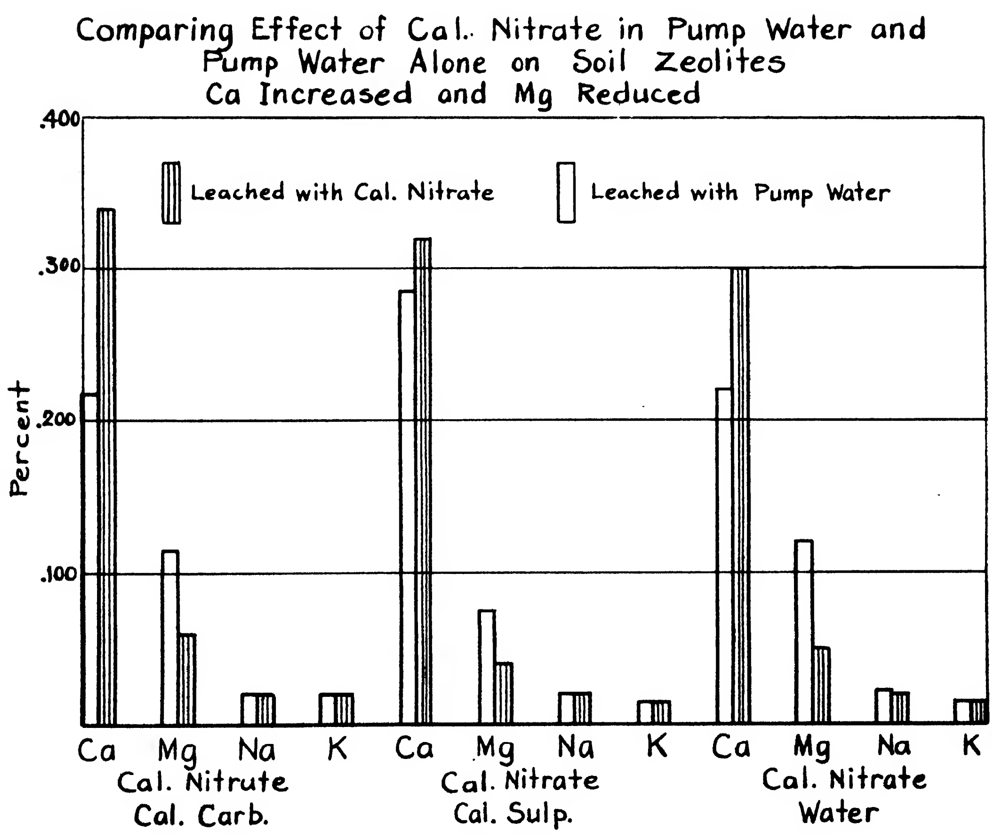
Comparing Effect of Cal. Nitrate in Pump Water and
Pump Water Alone on Soil Zeolites
Ca Increased and Mg Reduced
.400
Leached with Cal. Nitrate
Leached with Pump Water
.300
.200
.100
Percent
Ca
Mg
Na
K
Ca
Mg
Na
K
Ca
Mg
Na
K
Cal. Nitrute
Cal. Carb.
Cal. Nitrate
Cal. Sulp.
Cal. Nitrate
Water

Fig. 5

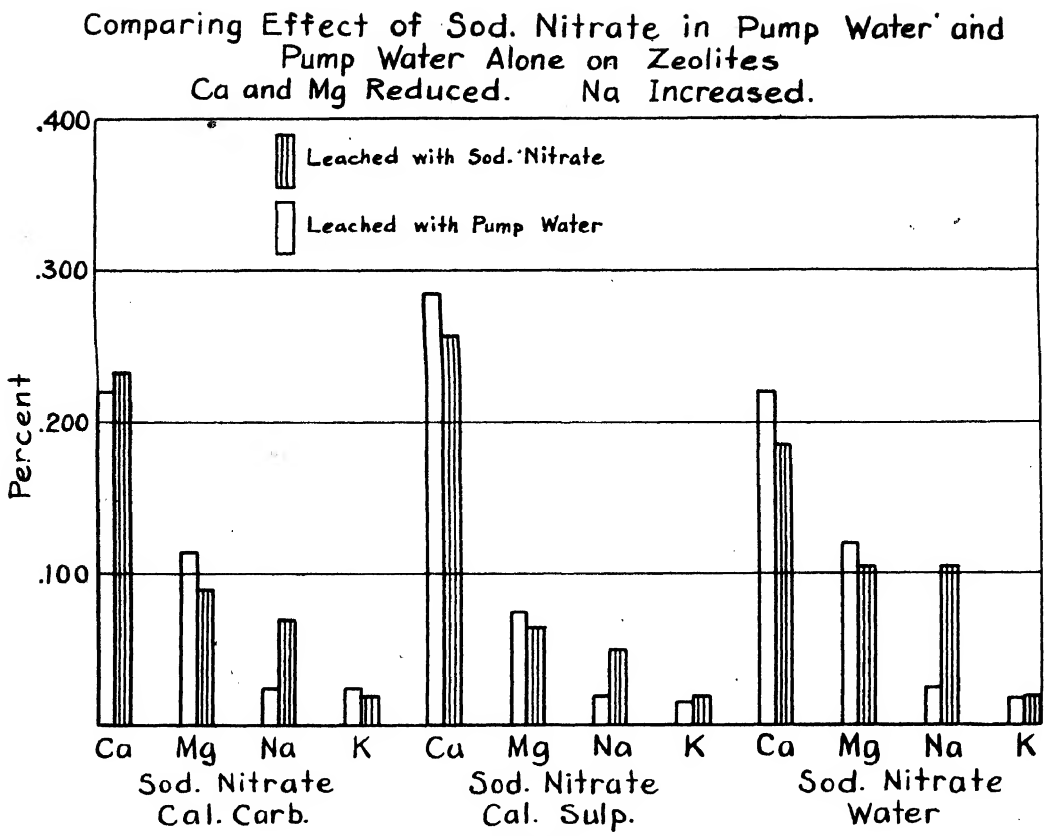
Comparing Effect of Sod. Nitrate in Pump Water and Pump Water Alone on Zeolites
Ca and Mg Reduced. Na Increased.
Leached with Sod. Nitrate
Leached with Pump Water
Percent
.400
.300
.200
.100
Ca Mg Na K Ca Mg Na K Ca Mg Na K
Sod. Nitrate Cal. Carb.
Sod. Nitrate Cal. Sulp.
Sod. Nitrate Water

Fig. 6

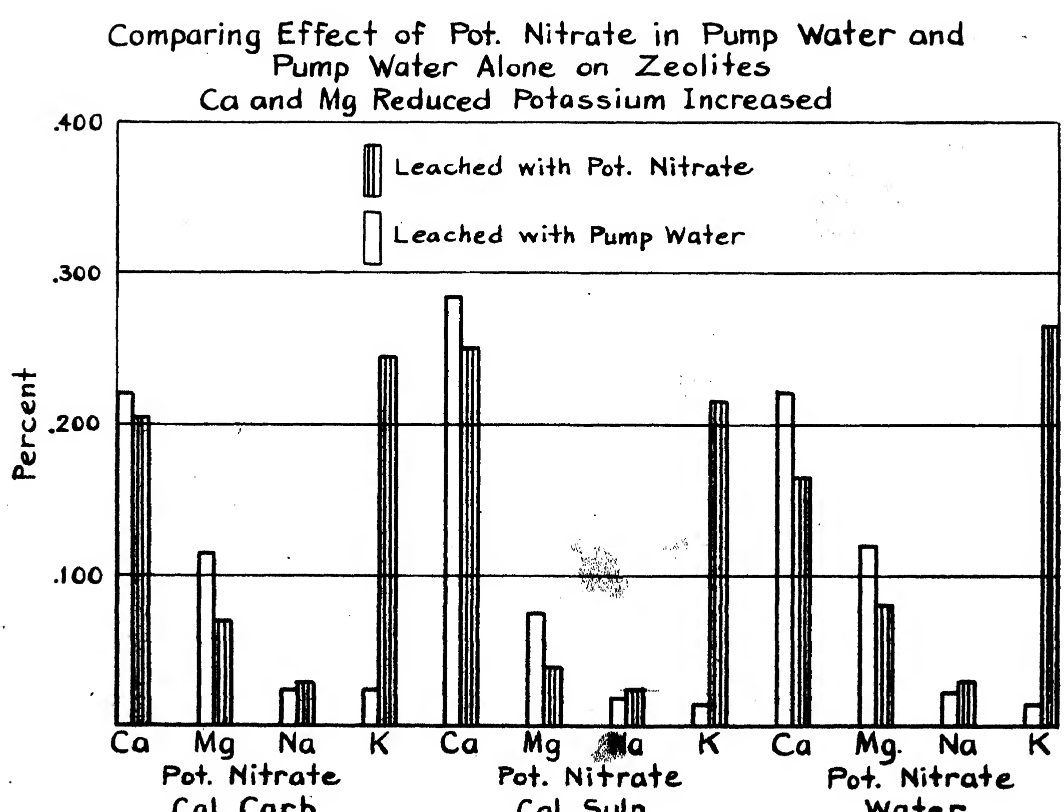
Comparing Effect of Pot. Nitrate in Pump Water and Pump Water Alone on Zeolites
Ca and Mg Reduced Potassium Increased
Leached with Pot. Nitrate
Leached with Pump Water
Percent
.400
.300
.200
.100
Ca Mg Na K Ca Mg Na K Ca Mg Na K
Pot. Nitrate Cal. Carb.
Pot. Nitrate Cal. Sulp.
Pot. Nitrate Water

Fig. 7

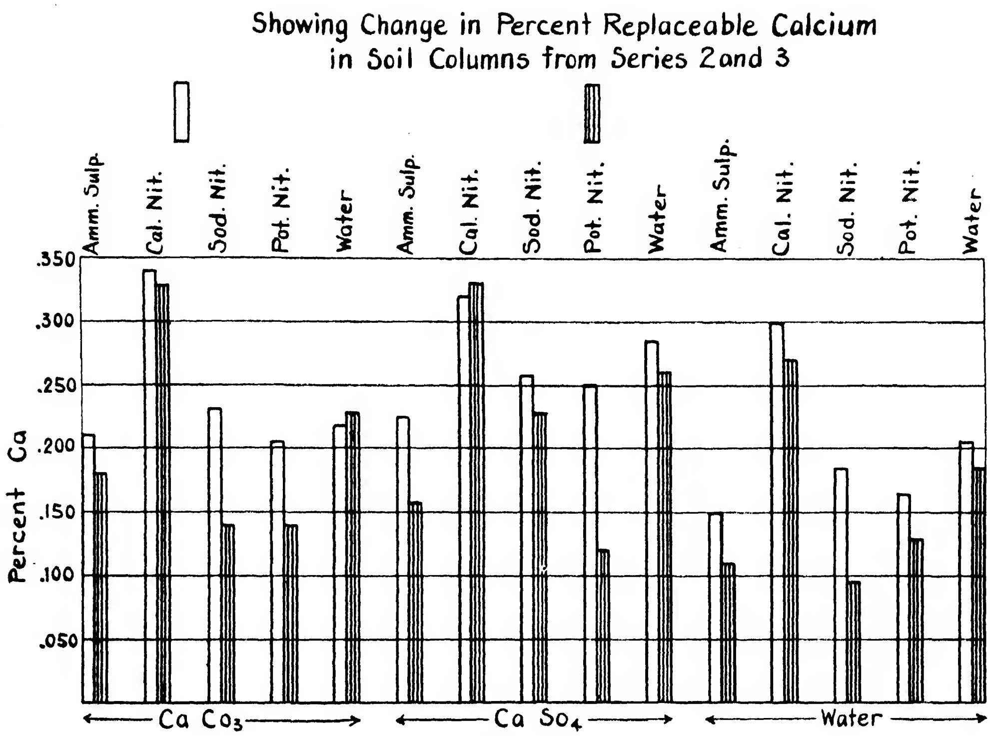
Showing Change in Percent Replaceable Calcium
in Soil Columns from Series 2 and 3
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Percent Ca
.350
.300
.250
.200
.150
.100
.050
Ca Co3
Ca So4
Water

Fig. 8

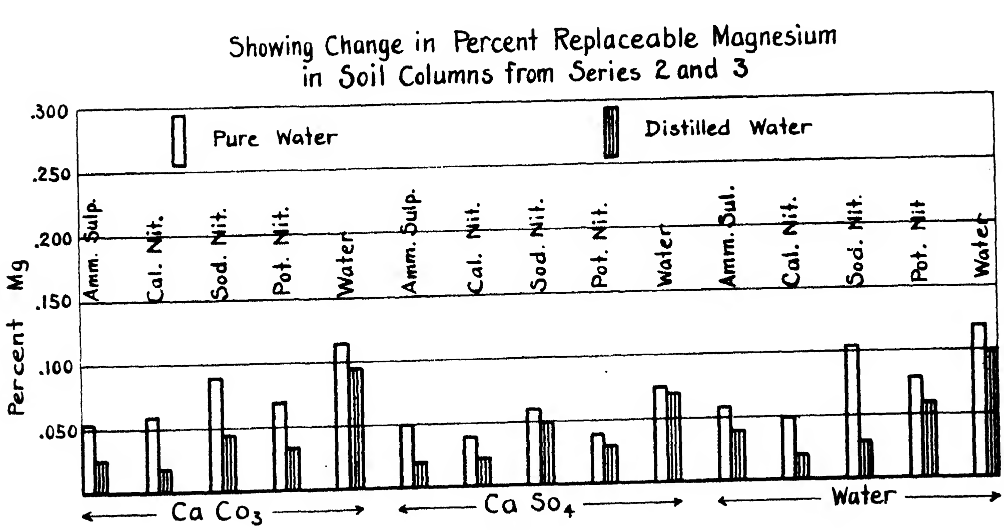
Showing Change in Percent Replaceable Magnesium
in Soil Columns from Series 2 and 3
Pure Water
Distilled Water
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sul.
Percent Mg
.300
.250
.200
.150
.100
.050
Ca Co3
Ca So4
Water

Fig. 9

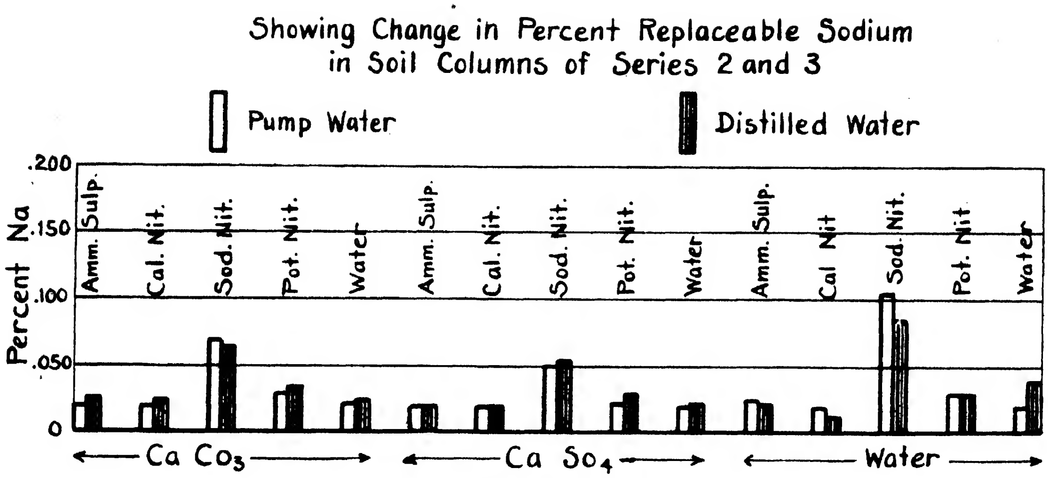
Showing Change in Percent Replaceable Sodium
in Soil Columns of Series 2 and 3
Pump Water
Distilled Water
Percent Na
.200
.150
.100
.050
0
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sulp.
Cal Nit
Sod. Nit.
Pot. Nit
Water
Ca Co3
Ca So4
Water

Fig. 10

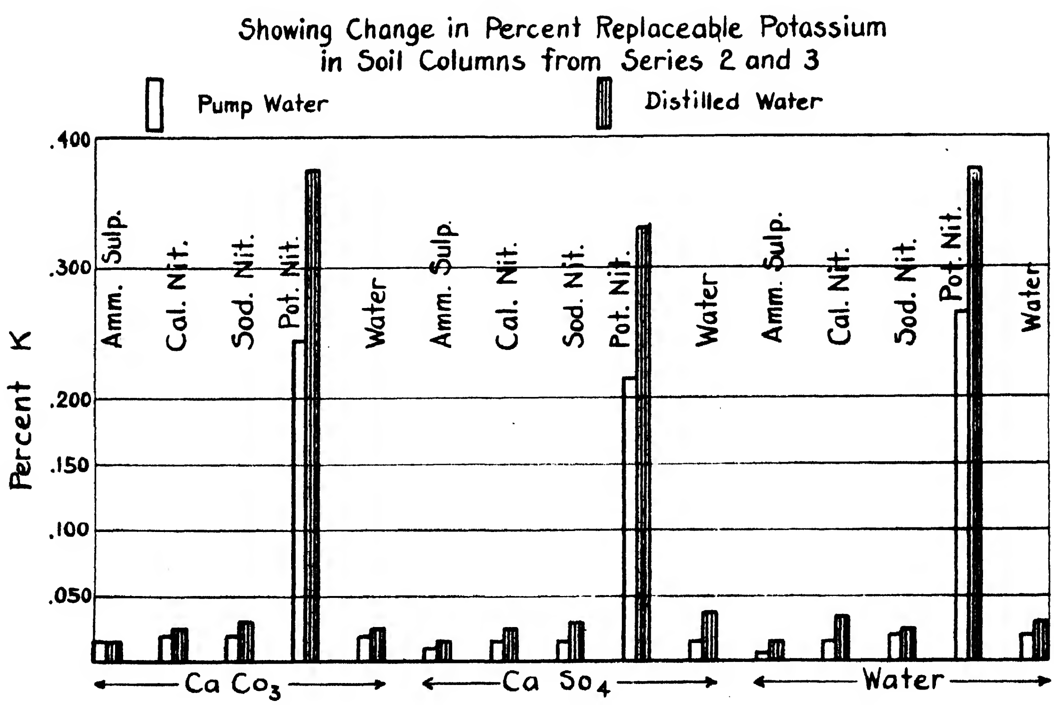
Showing Change in Percent Replaceable Potassium
in Soil Columns from Series 2 and 3
Pump Water
Distilled Water
Percent K
.400
.300
.200
.150
.100
.050
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Ca Co3
Ca So4
Water

Fig. 11

Notes on Irrigation Investigations and Control at Ewa Plantation Company

By H. R. Shaw

Plantation Irrigation Equipment

Supply: The Ewa Plantation Company is dependent on its artesian supply for irrigation. Rainfall in the Ewa district is extremely light, as is shown in the following table:

COMPARISON OF ANNUAL RAINFALL—EWA PLANTATION COMPANY

Year	Mill	Apokaa	9B Reservoir	Waimanalo	No. 6 Reservoir
1924	21.12	19.45	19.84	16.84	20.52
1925	10.04	10.01	10.18	6.34	10.58
1926	12.61	13.53	11.61	13.97	13.40
1927	41.25	47.53	50.82	43.22	46.63

The exceptionally high rainfall during the month of December, 1927, accounted for nearly half of the total rainfall for the year.

Pumps: The plantation has ten irrigation pumps in use. Nine of these are electrically driven, and the tenth is driven by steam. The maximum pumping capacity of the whole is 105 M. G. daily, but the average for the year is about half of this figure.

Field Layout: The so-called "Renton System" of irrigation has been adopted as the standard plantation practice. On the plant fields the watercourses are 70 feet wide, the length varying with the contour. The field is irrigated one line at a time until the cane is three or four months old and has closed in. The watercourse is then cut in the center, making two watercourses 35 feet wide instead of one watercourse 70 feet wide. Alternate lines are then cut to form a "U," and every two lines are irrigated as a unit. This system not only shows an advantage in increased acreage covered by the irrigator, but also gives an increased yield of sugar by the utilization of land formerly occupied by the additional watercourse.

Survey: All field surveys are of gross acreage, and are taken from a point two and a half feet out from the actual cane boundary. The survey includes all ditches in the area, but excludes roads. Watercourse areas are from center of watercourse to center of watercourse, and from center of level ditch to center of level ditch.

Ditch Lining: Although the plantation ditches, especially those on makai, coral soils, show a high seepage rate, there is little ditch lining being put in by the plantation. This is due to the fact that the plantation lease expires in a few years, and the management is avoiding permanent improvements of this nature.

Water Measurements

Equipment: The plantation has in use five standard rectangular weirs, five Steven and three Gurley water stage recorders, and about one hundred Lyman meters.

Installation: The Lyman meter installations now in use on the plantation have a depressed "V" basin, and have the meter box placed on the side of the ditch. The installation is at such a depth below the level of the ditch that the proportion between the orifice and the wetted area of the gate will be as 1 to 3. For instance, if a one-square-foot orifice is used, the total wetted area of the gate should be four square feet. This insures submergence of the orifice at all times.

The plantation formerly advocated a meter installation with the meter above the orifice and placed in the center of the gate, but the installation described above has been found to be preferable and is taking the place of the gate installation. All installations are of redwood at a cost of approximately $6.00 each. Because of the short duration of the plantation lease, it has been inadvisable to install concrete structures, although it is realized that this form is more economical for permanent installations.

Lyman Meters: Ewa is strongly in favor of the Lyman meter. Although its limitations are realized, it is felt to be the most practicable and economical device for measuring water under field conditions. J. B. Menardi, Jr., in charge of water measurements, says: "With close adjustment and care, in installations meeting the requirements of the meter, the Lyman will check within 3 per cent." Ewa also finds the Lyman meter valuable as a "policeman," in seeing that each of several fields on the same main ditch gets its share of water, and that no night water is being stolen.

The Lyman meters are checked against a "V" notch weir at the start of the irrigating season, and thereafter as necessary. It has been found that most inaccuracies of the Lyman meter occur at low heads: hence, the meter is checked against a small stream over the "V" notch weir rather than against greater heads. An installation for checking against a larger rectangular weir is also provided. A standard meter, which is kept at 100 per cent efficiency by frequent checking is substituted in the field installations during the course of the season to detect any inaccuracies in the field meters.

Irrigation Control

The entire plantation is under an extensive system of irrigation control. This control is based on the interval between irrigations rather than on the amount of water applied at each irrigation. It was found that the term "acre inches per acre" and "gallons per man" meant little to the average ditchman or irrigation overseer; while "number of days between irrigations" and "number of days per round" were readily applicable.

Type Fields: About 2,500 of the plantation's 8,000 acres are under actual meter measurement. Typical fields under the classification of "General," "Wet,"

"Coral" and "Pali" conditions have been chosen, and a series of interval tests installed in each of these type fields.

Interval Tests: In these interval tests, four treatments are given:

1. Maximum: in which an excessive amount of water is applied by irrigating at more frequent intervals.

2. Minimum: in which water is applied in the least amount possible for growth.

3. Normal; an optimum application, based on what the plantation treatment would be under ideal conditions as to water and labor.

4. Check: the application given by the plantation to the surrounding fields.

The intervals vary from 15 to 30 days, depending upon the soil type, the age of the cane, and the time of year. (For a more complete report on interval tests at Ewa, see "An Investigation to Determine the Relation of Water to Maximum Sugar Yield," Renton and Alexander, 1926.)

Growth Measurements: Correlated with the interval tests, growth measurements are made in each plot in order to determine at what interval optimum growth occurs. A minimum of twenty-five stalks is measured in each level ditch plot. From these data the optimum interval of irrigation of each soil type and for various ages of cane is determined, and a definite schedule of irrigation made. The data are interpreted liberally, and the irrigation schedule readjusted as further investigation may indicate.

Irrigation Schedule: The general irrigation schedule is as follows:

Irrigation No.	*Time*
1	Day planted.
2	Four days later.
3	Seven days later.
4, 5, 6	Ten days later.
7, 8	Ten to fifteen days later, depending on weather conditions.

From this time the irrigations are controlled by the irrigation schedule, depending on the month planted and the soil type.

Water Economy: From data gathered in these investigations, the problem of water application during the summer months when there is a scarcity of water has been solved for Ewa conditions. The young cane is forced by giving more frequent applications, and the more mature cane allowed to go with longer intervals. For instance, the irrigation schedule for the month of July, when there is a shortage of water, would be:

3 to 8 months cane........	15 to 20 days interval
8 to 12 months cane........	20 to 25 days interval
12 to 15 months cane........	25 to 30 days interval

Ripening Schedule: By correlating pre-harvest juice samples, growth, soil moisture and other related factors, an irrigation schedule for type fields during the three or four months directly preceding their harvest has been evolved. This includes the period during which irrigation is gradually retarded, in order to ripen the juice, and the period at which irrigation should completely cease.

Irrigation Reports

Staff: In addition to the men required for growth measurements, juice samples, etc., one member of the staff of the department of agricultural research and control, and two clerks (one man for control and one man for research) are used on the irrigation work alone. However, the ditchmen have been trained to adjust the orifice gates and take the meter readings, thus eliminating an otherwise expensive item in irrigation control.

Reports: The main irrigation reports used at Ewa are:

1. Irrigation Meter Record (Form I).
   Filled by overseer from readings supplied by the ditchman in charge of the field, and submitted after each day's irrigation.
2. Ditch Irrigations (Form II).
   Filled by the section overseer, and showing the number of ditches irrigated in his section daily.
3. Field Areas Irrigated (Form III).
   Showing percentage of field area irrigated daily, accumulated on the round to date, and the equivalent to this percentage in days performance as scheduled. Used as a basis for the Irrigation Control Board, to be described later.
4. Irrigation Daily Record Sheet (Form IV).
   Summary of labor, water, and round data for each field.
5. Growth Measurement Sheet (Form V).
   Detail and summary of growth measurements to each experimental field.
6. Irrigation Data (Form VI).
   A memorandum to section overseers, showing the actual result in water and labor used in each field as compared with the scheduled application as determined experimentally. A valuable report, in that it keeps the interest of the section lunas aroused, and shows them clearly the efficiency of their work.
7. Irrigation Record, Index Card (Form VII.)
   A convenient summary of irrigation results for each field. Kept in an index file for ready reference.
8. Growth Measurement, Index Card (Form VIII).
   A summary of cane growth, filed with the irrigation record.

FORM I

EWA PLANTATION COMPANY

Irrigation Meter Records

Field No. .... Ditch No. ....

Date .... Meter No. ....

ORIFICE FACTOR	READING
Start .... Finish	....
Start .... Finish	....
Start .... Finish	....
Total Acre Feet	
Men Irrigating	
Man Hours Irrigating	....
Deductions	NAME ....
ROUND	....

FORM II

DITCH IRRIGATIONS

Section No. 9 Antone Freitas.

FIELD	DITCHES PAU
"A" (8.04 Ac.)	....
"A" (38.30 Ac.)	....
"A" (and AS No. 4) (48.61)	....
"A" (78.58 Ac.)	....
"A" (110.47 Ac.)	....
"B"	....
"D" and A.S. No. 4	....
"E"	....
23-A Gulch	....
AS No. 1 (33.55 Ac.)	....
AS No. 1 (35.50 Ac.)	....
AS No. 2 (36.15 Ac.)	....
AS No. 2 (44.32 Ac.)	....
Rounds Pau	....
Date	....
By	....

FORM III

SCHEDULED INTERVAL	DAYS		MONTH OF AREA IRRIGATED		
DATE	IRRIGATED	DITCHES	% Daily	% Accumulated	In Days
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
Total					

1. Total acres of Experiments irrigated ....
2. Total acres of Dry Spotting ....
3. Total acres irrigated—excluding 1 and 2 ....

Grand total acres irrigated during month ....

Field.......... Experiment Area..........

Crop.......... Field Area.......... Total Area..........

FORM IV

FIELD OR LOCATION........................AREA........................MONTH OF........................192........

						ROUND DATA					
	MEN		ACRE FEET				MEN		ACRE FEET		
Date	I DS	Total	I DS	Total	Acre feet per man	Gallons per man applied	I DS	Total	I DS	Total
Forward										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										

MONTHLY SUMMARY

Average acre feet per acre........................ Avg. gallons per man per day........................

Average acre inches per acre........................ Avg. per man per day........................

Rainfall........................ Compiled by........................

Total acre inches per acre........................ Checked by........................

FORM V

GROWTH MEASUREMENT SHEETS

FIELD.................EXPERIMENT.................DITCH.................DATE.................192.........

Line	No.	Base to Top	Circum-ference	Line	No.	Base to Top	Circum-ference	Line	No.	Base to Top	Circum-ference
WC #	1			WC #	1			WC #	1		
	2				2				2		
	3				3				3		
	4				4				4		
	5				5				5		
	Avg.				Avg.				Avg.		
WC #	1			WC #	1			WC #	1		
	2				2				2		
	3				3				3		
	4				4				4		
	5				5				5		
	Avg.				Avg.				Avg.		

GENERAL SUMMARY

	Days	WC#	WC#	WC#	WC#	WC#	Mean Growth	Average Circum-ference
Base to Top								
Previous Base to Top								Cubic Inches
NET GROWTH								

Measured by.................Entered by.................Compiled by.................Checked by.................

FORM VI

IRRIGATION DATA

(Acre Basis)

Field.................................... Ditch....................................

Date....................................

	Average Practice	Actual
WATER		
Gals. per Man Day	....	....
Acre inches	....	....
LABOR		
Acres per Man Day	....	....
Interval	....	....

REMARKS

....

....

Report compiled

By whom....................................

Date....................................

FORM VII

ACME 7881-8 IRRIGATION RECORD________

AREA________________

ROUND NO.	DATE APP'L		INTER VAL DAYS	WATER APPLIED				LABOR		Rate of Flow	Monthly-Inches		
				ACRE-FEET		ACRE-INCHES							
	MONTH	DAY		TOTAL	PER ACRE	PER ACRE FOR RD.	DAILY BASIS	MEN ~~ROUNDS~~ TOTAL	ACRES PER MAN PER 10 HRS.	Gals per min per 10 hrs	Water	Rain	Total

FIELD DITCH TREAT

FORM VIII

NO. OF STALKS AVERAGED________ ACME 7882-8

EWA PLANTATION COMPANY

RECORD OF GROWTH MEASUREMENT AND CANE TONNAGE

DATE		INTER-VAL	ELONGATION OF STALK					CIRCUM-FERENCE INCHES	GROWTH CU. FT.	MONTHLY GROWTH % OF TOTAL	CANE PER ACRE PER MONTH TONS
					PRO-RATING						
MONTH	DAY		DURING PERIOD INCHES	DAILY INCHES	DAYS	RATE	MONTHLY INCHES				

FIELD DITCH TREAT

Irrigation Control Board

Purpose: Ewa Plantation Company has inaugurated a system of plantation control which has proved most effective in increasing the efficiency of irrigation, showing graphically to the plantation management the irrigation status and efficiency of each field, and in keeping the section overseers actively interested and alert in bettering irrigation conditions in their fields. The control board has been in use for over a year, and has proved highly successful.

EWA SYSTEM OF IRRIGATION CONTROL

Section								IRRIGATION SCHEDULE																													
Field No.	Acreage	Crop	Irrigation Round Interval-Days			Last Round Completed	Ac. per Man Day Last Rd.	Days of Present Round																													
			3	2	1			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
23 D	40.8	1929	x 14	34	18	Feb. 17	1.10	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	W	O	R	O	O	Y	O	O	O	O	O	O	O	O
24 B	18.7	1929	32	14	18	Feb 29	1.33	O	O	O	O	O	O	R	O	W	O	O	O	O	O	O	O	O	Y	O	O	O	O	O	O	O	O	O	O	O	O
20 A	64.5	1929	x 21	x 14	46	Feb 11.	-	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	RW	O	O	O	O	Y
B	175.3	1929	33	x 14	48	Feb 13	0.88	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	W	O	Y	G	O	O	O	O	O	O	O
								O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

Yellow Peg at "Optimum Interval"

Red Peg at "Number of Days since Round Started"

Green Peg at "Number of Days since Round Started" When Time elapsed exceeds optimum interval.

White Peg at actual interval Corresponding to "Area percentage Covered."

Field 23 D: Desirable interval is 22 days. Red peg shows 19 days already in field. White peg shows 17 days scheduled work completed. Irrigators 2 days behind schedule.
"X" designates previous round interrupted by rain.

Field 24 B: Desirable interval 18 days. Red peg shows 7 days already in field. White peg shows 9 days scheduled work completed.
Irrigators 2 days ahead of schedule.

Field 20 A: Desirable interval 30 days. Half red and half white peg shows irrigating gang on schedule.

Field B: Desirable interval 22 days. White peg shows 20 days scheduled work completed.
Green peg shows 23 days already in field, and that irrigating gang has exceeded desirable interval.

Optimum Interral Days

Actual Interval Days	1	2	3	4	5	6	7	8	9	10	11
	Percent of area irrigated to date										
1	100.0	50.0	33.3	25.0	20.0	16.7	14.3	12.5	11.1	10.0	9.1
2		100.0	67.7	50.0	40.0	33.3	28.6	25.0	22.2	20.0	18.2
3			100.0	75.0	60.0	50.0	42.9	37.5	33.3	30.0	27.3
4				100.0	80.0	66.7	57.2	50.0	44.4	40.0	36.4
5					100.0	83.3	71.5	62.5	55.5	50.0	45.4
6						100.0	85.7	75.0	66.7	60.0	54.5
7							100.0	87.5	77.9	70.0	63.7
8								100.0	89.0	80.0	72.8
9									100.0	90.0	81.9
10										100.0	90.9
11											100.0

This Sheet gives "Actual Interval" relative to "Optimum" When "Percent of area to date" (See Form III) is known.

A White peg is placed in hole corresponding to this "Actual Interval."

Example: A field having an optimum interval of 11 days has been irrigated for 7 days during the present round. In this time the irrigating gang has completed 72.8% of the total field area. Under "11" in the optimum interval column, we find 72.8% equivalent to 8 days actual interval (by following the horizontal column to the left.) Hence, the yellow peg would be under "11" on the board; the red peg at "7" and the white peg at "8"

H. R. S.
Mar. 1928.

The accompanying illustration shows the general principles involved in handling the board.

The optimum interval for each field is taken from the irrigation schedule, and is based on experimental results in the soil section to which the field belongs. A yellow peg is placed under the day on which the irrigation should be completed.

The red peg represents the actual days of irrigation. It is advanced one space for each day of irrigation in the field.

The white peg represents the actual amount of work that is being done as compared to the scheduled time. If, for instance, an optimum ten-day interval had been fixed, the irrigators should cover 10 per cent of the total field area per day. If they should do 40 per cent of the field on the first day, they will have done four days scheduled work and are three days ahead of schedule. Thus, in this case, the white peg would be placed four spaces from the right of the board. The percentage of the field covered is taken from "Field Area Irrigated" (Form III).

If the irrigators are exactly on schedule, a red-and-white peg is used, as this represents the "number of days since round started," coinciding with "number of days scheduled." If the actual number of days in the field exceeds the optimum interval, a green peg is substituted for the red one to show that that field is operating below efficiency.

By such a system, the section lunas and the head overseer can more easily place men for each day's work, as they can readily see if a field is ahead or behind schedule, and can move irrigators to or from a field in order to maintain a proper balance of labor.

Additional Experiments

Policy: The present policy of the Ewa Plantation Company is to continue the experiments now in progress without adding extensively to their system of meter measurement. This is partially due to the fact that the short duration of their lease would not make it economical to expand in this line, and partially because the management feels that their present system should be perfected before additional work is done. W. P. Alexander, agriculturist, says: "Any system of water measurement should be based on experimentation. We feel that to merely measure the water going to the field, or to create a water balance between water pumped and water consumed in the field is of little value. We prefer to get exact data on smaller areas, representative of the whole plantation, and to apply data thus gained to the plantation in general, rather than to attempt to cover every field by irrigation measurement."

New irrigation experiments to be made will be for the purpose of correcting present errors in the plantation cultivation system. Experiments in ratooning are now under way, the problem being to determine whether it is better practice in saving water and in general economy to do a thorough and expensive job of ratooning at $6.00 or $8.00 per acre, or whether to do a less expensive piece of work at about $2.00 per acre. In other words, "just how thorough ratooning is necessary for economical sugar production?"

Another problem to be solved is: "During a period of water shortage, should cane on loam soils, or coral soils, be forced?" The plantation has already found it better economy to push the young cane during the summer, but whether better yields can be made by applying this water to loam fields where the water retention capacity is relatively high, or to coral fields that demand a great deal of water, is yet to be decided.

ADDENDA

Since the foregoing report was written, the plantation management has introduced an added improvement in its system of irrigation control as applied to the individual fields.

Under the previous system, water applications to the field were based on the interval since the last irrigation and on the number of days in which the current round should be completed. In this way it was possible for the period from start of round to finish of round to be completed in the scheduled number of days; but there was no assurance that each ditch within the field would be irrigated at the proper interval in relation to that particular point in the last irrigation. A few irrigators might start the round to a certain field and be able to cover only a small percentage of the area, due to lack of water. On the next day more water might be available, and the irrigators could work more rapidly and complete a greater area. If the irrigation control board showed the irrigators falling behind schedule, the section overseer would put more irrigators in the field in an attempt to finish the irrigation quickly and on the time schedule set for the entire field. Hence, by this variation in daily area covered, depending on the number and speed of the irrigators and on the water available, the entire field, from starting point to finishing point, might be completed in the scheduled interval of, say, 20 days, but there would be a variation in interval of from 14 to 28 days in the irrigation of specific ditches within the field.

To remedy this condition, an interval schedule for each ditch in the field has been set. The section overseer now knows exactly the number of ditches he should irrigate each day, as well as the number of men and the amount of water he will require. This system of application is valuable not only in keeping each part of the field on schedule, thus assuring the best growing conditions, but also in making it possible to give additional dry spot irrigations to ditches which have been found to demand more water than other parts of the field.

Reports from the section overseers have now been standardized and simplified by including all routine reports in one loose-leaf notebook. This report book consists of four parts:

1. *Time Book:* The daily time sheet for all fields on the section is kept in the front of the book. The loose-leaf sheets can be easily removed, left with the timekeeper for entering, and returned to the section luna for filing.

2. *Irrigation Report:* The scheduled date for irrigation of each ditch in the field is set a month in advance by the Department of Irrigation Control. The section overseer, by referring to the schedule in his notebook, attempts to keep his irrigations on schedule and marks the date on which the application was completed.

He records the number of men irrigating daily in each ditch, the date on which the ditch irrigation was completed, and sets the date for the next irrigation of the ditch.

3. *Ripening Schedule:* Fields in the ripening zone which do not come under the regular irrigation rounds have a special schedule designed to gradually ripen off the field. By the use of this record, an exact history of each ditch will be maintained, while, previously, data were available only on the entire field.

4. Maps and blue prints of the fields in the section as well as special data and reports are kept in the back of the book.

The Introduction of Anaphoidea Calendrae Gahan Into Hawaii as a Possible Egg-Parasite of Our Sugar Cane Beetle Borer, Rhabdocnemis Obscura (Boisd.)

By Francis X. Williams

As a result of correspondence between Mr. C. E. Pemberton, Associate Entomologist of this Station, and Mr. A. F. Satterthwait, in charge of the United States Entomological Laboratory at Webster Groves, Missouri, I was detailed to proceed to Webster Groves for the purpose of accumulating and bringing back a quantity of living material of the tiny *Anaphoidea* wasp, known to be parasitic on the eggs of billbugs (*Calendra* spp.), that it might be liberated in Hawaii as a possible egg-parasite of our sugar cane beetle borer (*Rhabdocnemis obscura*). I arrived at Webster Groves on May 10 and completed my work there on July 21; reached Honolulu on July 31, and Paauhau, Hawaii, where most of the parasites were liberated, on August 1, 1928.

But for the aid given me by Mr. Satterthwait, this work could scarcely have been accomplished in one season. In anticipation of my arrival at Webster Groves, he had arranged for the collection of thousands of living billbugs—as egg producers—turned over for my use a considerable part of the laboratory, gave me the help of others of his staff, and freely of his own time and experience; and in addition, there was his excellent entomological library ready at hand.

Billbugs are a group of weevils, and are so named because of the beak or "bill" which forms so prominent a portion of their features. One of the species is known as the "curlew-bug," and anyone who is acquainted with both bird and beetle can readily detect a resemblance between the two. These snout beetles range in size, according to species, from considerably smaller to much larger than our sugar cane beetle borer, and so, too, do the eggs vary. There is usually but one brood a year. As a rule billbugs pass the winter in the adult stage. They lay eggs in

spring and summer; these hatch in from four to fifteen days; the resulting grubs feed for a few weeks to well over two months, when they transform to pupae that in a week or so produce the adults that are destined to hibernate. Some of these insects are well known to the farmer, for they are destructive to cereal and forage crops, not only as larvae, but frequently, too, as adults. We have but to mention here such pests as the timothy billbug (*Calendra zeae*), the maize billbug (*C. maidis*), and the blue-grass billbug (*C. parvulus*).

Billbugs in general bear a good deal of natural resemblance to our sugar cane beetle borer. Indeed, in bygone days, when classification was not so discriminating, both groups were placed under the genus *Sphenophorus,* but later they were separated out as *Calendra* and *Rhabdocnemis.* Like the sugar cane beetle borer, many billbugs bite a small hole or cell into the plant tissue, turn about and deposit an egg therein, and the short, paunchy grubs of each genus are very much alike, and so, too, the pupae.

It was years ago, while working on the biology of his favorite group, the billbugs, that Mr. Satterthwait made the discovery that some of their eggs were parasitized by a tiny blackish wasp less than a millimeter in length. The insect was later described as *Anaphoidea calendrae.* Its wings are fringed with long hairs, and it belongs to the wasp family Mymaridae, which includes our *Paranagrus,* leafhopper egg parasites. Mr. Satterthwait succeeded in rearing many generations of *Anaphoidea* and found that their complete life-cycle involved from fourteen to about seventeen days, depending largely upon temperature. Also, that these wasps did not breed successfully in any but comparatively fresh *Calendra* eggs. He found, however, that they readily accepted for oviposition therein the eggs of some half dozen or more species of these billbugs. Such eggs, though they varied greatly in size, must all have had some sort of *Calendra* odor, taste or texture acceptable to the parasite. Furthermore, from a few to many individual wasps issued from each parasitized *Calendra* egg, said number being determined in part by the size of the egg host and (or) by the degree of its parasitism, the writer having obtained seven females and one male *Anaphoidea* from a single egg of *Calendra maidis* on one occasion, and on another, eighteen females and three male wasps from an egg of the same species. While eggs of the smallest billbug at Webster Groves may sometimes disclose but two or three parasites, the yield in nature is normally six or seven adult wasps per such an egg. The size of the individual wasp is also correlated with that of the billbug egg. The female wasp is almost invariably produced in far greater numbers than the male.

Mr. Satterthwait has a great deal of data on this *Anaphoidea* parasite, which it is hoped will soon be published.

The fact that *Anaphoidea* successfully parasitizes the eggs of many species of billbugs, cousins to *Rhabdocnemis,* fully justifies, we believe, the attempt made to establish it on the beetle borer in Hawaii.

Billbugs collected before my arrival in Webster Groves, and also subsequent thereto, were placed in metal salve boxes, usually partly filled with soil, and provided with grains of corn as food, and put in a refrigerator to retard their activities

until *Anaphoidea* wasps could be obtained from the field. Billbugs are very hardy and stand refrigeration—even out of season—quite well.

Since the *Anaphoidea* wasp passes the winter in the eggs of its host, a quantity of last year's (1927) grass stems, particularly of timothy (*Phleum pratense*) was brought into the laboratory and placed in tight boxes in which two holes had been drilled for the insertion of testtubes to draw to light the insects that emerged in these boxes. In this wise, timothy stems boxed on May 19, yielded on May 23 and 24, two male and three female *Anaphoidea* wasps, probably derived from a single parasitized *Calendra* egg. These wasps, however, failed to parasitize the billbug eggs offered them. Since it was now obvious that *Anaphoidea* had already emerged from winter quarters, and that for some time billbugs had been laying eggs in the field, a search for parasitized billbug eggs laid in green grass stems, at or near their base, was undertaken, with the result that on June 5, thirteen eggs of *Calendra minima*, a small species of billbug, were found in Red top grass (*Agrostis alba*), and one of these eggs showed by its mixed slaty black and whitish color that it was parasitized by *Anaphoidea* in an advanced stage of development, the individual wasps themselves being more or less discernible therein. Very soon thereafter, other parasitized *minima* eggs were found by Mr. Bucholtz, assistant to Mr. Satterthwait and by myself. It was from seven parasitized *minima* eggs, termed generation A for convenience, that the *Anaphoidea* stock, generation D, was derived, and that was liberated two months later in the cane fields of Hawaii.

Billbugs were taken out of cold storage as needed and fed in part with timothy bulbs, and in part with pieces of green corn stems obtained from the southern states, at first in small quantity, but later on in ample amounts. The green corn stems proved best, both as billbug feed and as a medium for egg laying, for they could be easily split up and examined. This daily work of feeding the billbugs, of cutting their eggs out of the plant tissue, and of exposing them for parasitization, soon assumed large proportions, so a young assistant, Mr. Ralph Swain, was engaged to take over most of this routine work, which he did very creditably.

The *Calendra* eggs were usually placed along the trough of a split grass stem serving as a carrier and so exposed in slender testtubes to *Anaphoidea*. As the work went on and more billbug eggs and wasps became available, larger tubes were often used and the eggs arranged on a piece of corn rind. The *Anaphoidea*, in number from a half dozen or so to perhaps fifty or more, were kept in these egg-charged tubes from a few hours to a day or more. As a rule, some of the wasps immediately became interested in the eggs, tapped them with their feelers, and pierced certain of them with their rather long ovipositor. Rarely, however, did I obtain more than 50 per cent parasitism, usually much less. This state of affairs was probably in part due to some fault in the technique, and to the fact that some of the billbug eggs had lost their attraction through age. The wasps, too, are not so easy to handle as many other small parasites, and in captivity live only four or five days; less in very warm weather. Following Mr. Satterthwait's method, these exposed billbug eggs were placed each in a little depression in the clean soil in a metal salve box, and the lid put on; thus about the right degree of moisture was secured for them and they kept very well. Two or three days after being exposed

to *Anaphoidea,* white blotches or areas appeared in certain eggs, showing that these had been parasitized. Some days later the eyes of the *Anaphoidea* pupae could be seen through the egg shell, and finally the slaty black markings, mingled with whitish, denoted eggs near to disclosing adult wasps. The wasps escape from the billbug egg through one or more holes. A few are weaklings, however, and perish within the shell.

The A generation of seven eggs secured from the field in early June produced 41 *Anaphoidea* wasps. These were given a total of 311 billbug eggs, chiefly those of *Calendra parvula, zeae, scoparia* and *maidis,* between June 10 and 22, when the last *Anaphoidea* died. This A generation successfully parasitized approximately 43 of these *Calendra* eggs, that gave rise to a B generation of 189 wasps. From June 25 to July 6, this generation was offered about 1,400 billbug eggs, mainly *C. maidis,* a large species that lays an egg much larger than that of our sugar cane borer, and that proved the most available as well as otherwise the most satisfactory billbug to work with. The C generation resulting amounted to about 100 parasitized billbug eggs. Most of these eggs were kept in the comparatively cool cellar for a time so that the wasps would not hatch too soon, otherwise some of their earlier progeny (D generation) might issue during the Missouri-Hawaii journey. From July 15 to July 21, the day of departure from Missouri, a total of about 2,000 eggs of *Calendra maidis* were exposed to the several hundred wasps that issued from the 100 or so parasitized eggs. The results were rather disappointing, as the D generation was only slightly greater than C, and only so because practically all parasitized eggs were large eggs, and perhaps a greater percentage of them hatched successfully. The first parasitized eggs of this D generation were kept in refrigeration for from one to two days, to retard their development, for at that time the temperature at Webster Groves ranged around 90° F. and some eggs in the warmer part of the laboratory were collapsing. This lot of slightly over 100 parasitized maize billbug eggs was readily transported to Hawaii in depressions in moist clay in metal salve boxes, the first *Anaphoidea* issuing on the morning of August 2, the day after their arrival at Paauhau Sugar Plantation. By the afternoon of August 6, some 700 wasps had hatched. These were promptly liberated in cane fields Nos. 6 and 14A of this plantation, and where conditions seemed best for their success, beetle borers being present there in plenty and traps consisting of pieces of sugar cane, split or intact, having been placed therein to concentrate the borers and thus, too, their eggs.

While at Paauhau, I offered about a dozen fresh beetle borer eggs to a large number of *Anaphoidea* parasites, the offering being distributed over three days. Contrary to my expectations, the wasps were very indifferent to these beetle borer eggs, in striking contrast to the behavior of many of them towards billbug eggs in Missouri. None of these twelve cane borer eggs produced parasites. Possibly, however, conditions in the canefields may prove more inviting to *Anaphoidea.* A certain number of eggs of the lot D did not produce wasp parasites until after my departure, on August 4, from Paauhau. Instructions were left, however, to liberate whatever wasps hatched therefrom in field 14A. About 40 wasps were also turned loose in the Manoa Substation cane, Honolulu, on August 7.

As a secondary project, 102 adults of *Scarites,* a more or less subterranean ground beetle—the larva dwelling entirely underground—were collected under stones, logs, etc., at Webster Groves, and were mailed as well as brought in to Honolulu and released in field No. 41, Oahu Sugar Company, in the hope that these predaceous insects will become established and prey upon the grubs of *Adorctus sinensis,* the Chinese rose beetle.

Finally, a total of eight females and seven males of *Rhinopsis caniculatus,* a wasp that in Missouri parasitizes certain native wood cockroaches (*Parcoblatta*), and in the laboratory in Honolulu found also to prey upon *Loboptera sakalava,* one of our commonest field roaches, as does likewise *Dolichurus stantoni,* the Philippine roach wasp now established in the Hawaiian Islands, were liberated August 8, below the Nuuanu Pali, and at the Manoa Substation.

In Farmers' Bulletin 1003, United States Department of Agriculture, January, 1919, and written by A. F. Satterthwait, is a brief and well illustrated treatise on billbugs and their control.

Anaphoidea calendrae, the billbug egg parasite, is described by Gahan in the Proceedings of the United States National Museum, Vol. 71, pp. 32-35, Fig. 2, 1928.

Molasses, Press Cake, Bagasse, and Ash Mixtures as Fertilizer

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By J. A. Verret and R. E. Doty

Soil Used

This work was carried on at Makiki in a series of concrete tubs holding eight cubic feet of soil each. The soil used was a poor mauka one obtained at the Manoa substation.

The department of chemistry gives the composition of this soil as follows:

	1 Per cent Citric Acid Soluble				Strong HCl Soluble			Total by Fusion		
Soil Reaction pH	Silica SiO_2	Lime CaO	Potash K_2O	Phos. Acid P_2O_5	Lime CaO	Potash K_2O	Phos. Acid P_2O_5	Potash K_2O	Phos. Acid P_2O_5	Nitrogen N
5.3	0.10	0.49	0.062	0.0033	0.94	0.11	0.14	0.36	0.26	0.28

From the above we see that this soil is decidedly acid and has a low content of available phosphate. There is a good supply of available potash in the soil, but there is a slightly low content of total reserve potash and phosphates.

Composition of the Mixture (Molasses Cake*)

The mixture used had the following composition by weight:

Molasses	48.5 per cent
Press cake	33.8 per cent
Bagasse	12.2 per cent
Ashes	5.5 per cent

Its analysis follows:

0.40 per cent nitrogen	8 pounds per ton
0.81 per cent phosphoric acid	16 pounds per ton
2.65 per cent potash	53 pounds per ton
1.09 per cent lime	22 pounds per ton

The main object in making this mixture is to facilitate the transportation of the molasses. To many poor, mauka fields which are likely to be most in need of molasses treatments, it is not practical to transport molasses as such. When incorporated in a mixture as above it becomes purely a matter of cost versus the benefits to be derived.

Details of Application and Treatments Given

Where it is cheaper to put the molasses and press cake separately on fields which are to be plowed, we, as yet, see no reason why it should not be done instead of going to the extra expense of making the mixture.

When used the molasses mixture was well incorporated in the top foot of soil only.

Three-eye cuttings from which the two end eyes had been gouged out were used for seed. These were started in germinating trays and when planted in the tubs every care was taken to use plants of uniform size.

This pot test can be used only as an indicator of the trend of results, as the number of large sized pots was necessarily so limited that proper repetition was impossible. Therefore, we should keep its limitations in mind as we study the following data:

* This term is applied to a mixture of molasses, filter press cake, bagasse, and furnace ash.

Table I

The treatments given the various tubs are shown in the following tabulation:

Tub	Treatment at planting time	Fertilizer applied 56 days after planting	Fertilizer applied 3½ mos. after planting	Total pounds P.A. N	P_2O_5	K_2O
Tub 2	Check—no treatment		100 lbs. N 100 lbs. P_2O_5 100 lbs. K_2O	100	100	100
4	" " "			100	100	100
Tub 1	Molasses cake 20 T.P.A.		No treatment	160	320	1060
3	" " " "		100 lbs. N	260	320	1060
Tub 5	Molasses cake 20 T.P.A.	100 lbs. N 100 lbs. P_2O_5 100 lbs. K_2O	No treatment	260	420	1160
7	" " " "		100 lbs. N	360	420	1160
Tub 6	No molasses cake	100 lbs. N 100 lbs. P_2O_5 100 lbs. K_2O	No treatment	100	100	100
14	" " "		100 lbs. N	200	100	100
Tub 19	Molasses cake 5 T.P.A.		No treatment	40	80	265
22	" " " "		100 lbs. N	140	80	265
Tub 18		Molasses cake 5 T.P.A.	No treatment	40	80	265
20		Molasses cake 5 T.P.A.	100 lbs. N	140	80	265
Tub 21		Molasses cake 5 T.P.A. + 100 N; 100 P_2O_5 + 100 K_2O	No treatment	140	180	365
23			100 lbs. N	240	180	365

Tub	Treatment applied 2 months before planting	Fertilizer applied 56 days after planting	Fertilizer applied 3½ mos. after planting	Total pounds P.A. N	P_2O_5	K_2O
Tub 9	Check—no treatment			...	...	....
11	" " "			...	...	....
Tub 8	Molasses cake 20 T.P.A.		No treatment	160	320	1060
10	" " " "		100 lbs. N	260	320	1060
Tub 12	Molasses cake 20 T.P.A.	100 lbs. N 100 lbs. P_2O_5 100 lbs. K_2O	No treatment	260	420	1160
15	" " " "		100 lbs. N	360	420	1160
Tub 13	Molasses cake 20 T.P.A.		No treatment	260	420	1160
16	100 N; 100 P_2O_5; 100 K_2O.		100 lbs. N	360	420	1160
Tub 17	Molasses cake 40 T.P.A.		No treatment	320	640	2120
24	" " " "		100 lbs. N	420	640	2120

Table II

The treatments including total plant food applied as commercial fertilizer with the harvesting weights are given in the following table:

Treatment at planting time. Amounts of molasses cake only listed		Total plant food applied. Obtained from molasses cake and chemical fertilizer together			Harvested Sept. 20, 1928—age 7 mos. 24 days	
		N	P_2O_5	K_2O	Millable Cane	Total weight of green material
Tub 2	Check—no molasses cake	100	100	100	379	921
4	" " " "	100	100	100	1120	2044
Tub 1	Molasses cake 20 T.P.A.	160	320	1060	239	916
3	" " " "	260	320	1060	1852	2817
Tub 5	Molasses cake 20 T.P.A.	260	420	1160	1624	2807
7	" " " "	360	420	1160	5122	7855
Tub 6	No molasses cake	100	100	100	422	820
14	" " "	200	100	100	3095	4875
Tub 19	Molasses cake 5 T.P.A.	40	80	265	544	1159
22	" " " "	140	80	265	1543	2636
Treatments 56 days after planting:						
Tub 18	Molasses cake 5 T.P.A.	40	80	265	564	1028
20	" " " "	140	80	265	2470	3954
Tub 21	Molasses cake 5 T.P.A.	140	180	365	328	779
23	" " " "	240	180	365	3765	5607
Treatments applied 2 months before planting:						
Tub 9	Check—no treatment	...	...	....	209	688
11	" " "	...	...	....	262	642
Tub 8	Molasses cake 20 T.P.A.	160	320	1060	1022	1924
10	" " " "	260	320	1060	3435	5921
Tub 12	Molasses cake 20 T.P.A.	260	420	1160	2592	4014
15	" " " "	360	420	1160	9775	13157
Tub 13	Molasses cake 20 T.P.A.	260	420	1160	1385	2314
16	" " " "	360	420	1160	5470	8274
Tub 17	Molasses cake 40 T.P.A.	320	640	2120	1234	2297
24	" " " "	420	640	2120	4102	6486

Time of Application of Molasses Cake

In the table given below we have segregated the pots and yields according to whether the molasses cake was put on at planting time or two months before planting. Other fertilization was uniform for the corresponding pairs.

Table III

Molasses cake at planting time			Molasses cake 2 months before planting		
Tub No.	Millable cane gms.	Total weight of green material	Tub No.	Millable cane gms.	Total weight of green material
1	239	916	8	1022	1924
3	1852	2817	10	3435	5921
5	1624	2807	12	2592	4014
7	5122	7855	15	9775	13,157
Total	8837	14,395	Total	16,824	25,016
Average	2209	3599	Average	4206	6254
Gain				1997	2655
Gain per cent				90.4	73.8

These figures show significant gains in favor of applying the molasses cake two months before planting.

This is in line with results obtained in other places when working with molasses. Under most conditions it has been found more satisfactory to apply the molasses before planting rather than on the growing crop.

In Hawaii recent trials have shown marked response on the part of sugar cane when the molasses was applied with the first water after planting. In other cases the same procedure has lowered germination and checked early growth. It is unquestioned that it is a better procedure to apply the molasses as early as possible; before planting in the case of fields to be plowed.

The reason for the check in growth which often occurs when molasses is applied to a growing crop is believed to be due to the fact that in decomposing, the molasses has a denitrifying action on the nitrates in the soil. The reaction is much stronger on some soils than on others.

In the test being reported we had a gain of approximately 75 per cent in favor of the early application. These results are significant in that there were no exceptions, that is, all pots which received the molasses cake two months before planting produced much larger yields than those to which the mixture was applied later, as shown in Table III. (See Fig. 1.)

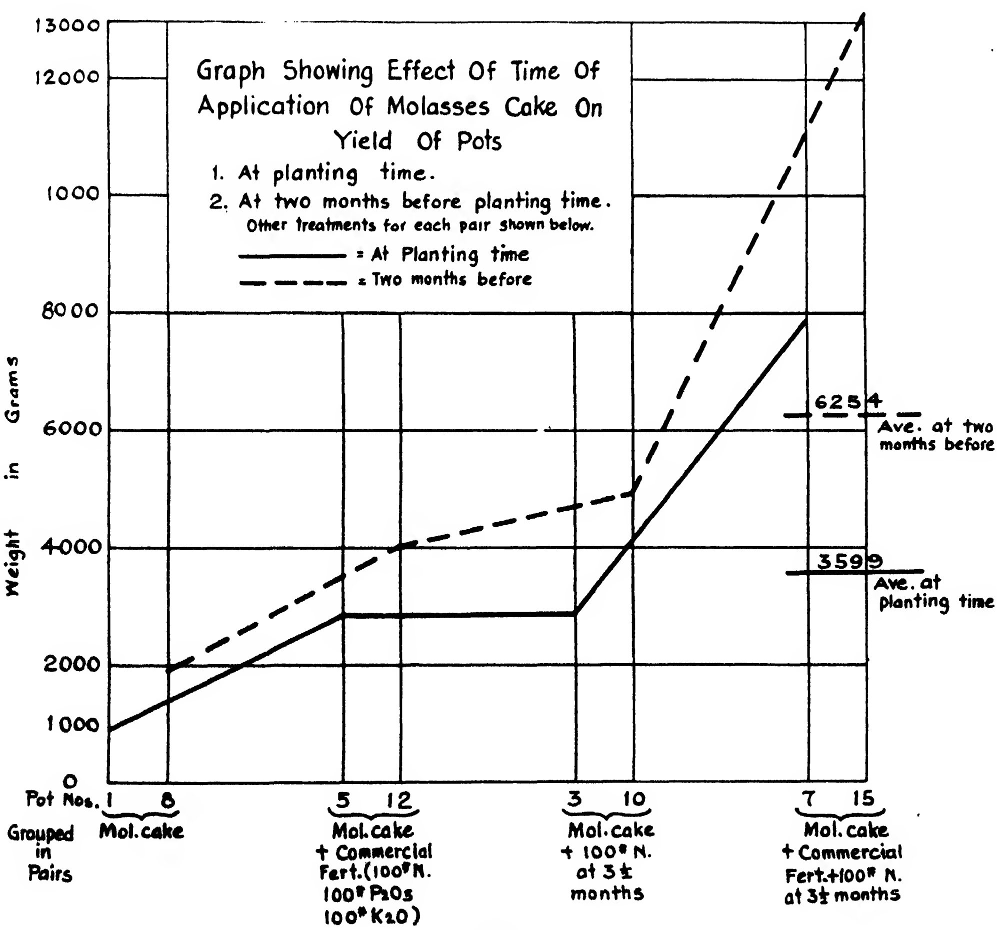


Fig. 1

Time of Molasses Cake Application in Connection With Complete Fertilizer

The time of application of the molasses cake and commercial fertilizer has a definite effect on the growth as illustrated in the tabulation below:

Table IV

Molasses cake late (planting time); fertilizer late (56 days after planting)

Pot No.	Total plant food N	Total plant food P_2O_5	Total plant food K_2O	Millable cane	Total green weight
5	260	420	1160	1624	2807
7	360	420	1160	5122	7855
Average				3373	5331

Both molasses cake and fertilizer applied early (2 months before planting)

Pot No.	Total plant food N	Total plant food P_2O_5	Total plant food K_2O	Millable cane	Total green weight
13	260	420	1160	1385	2314
16	360	420	1160	5470	8274
Average				3427	5289

Molasses cake early (2 months before planting); fertilizer late

Pot No.	Total plant food N	Total plant food P_2O_5	Total plant food K_2O	Millable cane	Total green weight
12	260	420	1160	2592	4014
15	360	420	1160	9775	13157
Average				6183	8595

In Table IV we show the effect of time of application of the various ingredients when both molasses cake and commercial fertilizers are used.

The best results were obtained when the molasses cake was applied two months before planting and the fertilizer two months after. Next was when both the molasses cake and fertilizer were applied two months before planting. These results were closely approximated when the molasses cake was applied at planting time and the fertilizer two months later.

Molasses Cake and Commercial Fertilizer

Table V-A

No treatment			Molasses cake 20 T.P.A. only Plant food equivalent (160 N, 320 P_2O_5, 1060 K_2O)		
Tub No.	Millable cane gms.	Total weight gms.	Tub No.	Millable cane gms.	Total weight gms.
9	209	688	8	1022	1924
11	262	642	1	239	916
Totals	471	1330	Totals	1261	2840
Average	235	665	Average	630	1420
Gain produced by molasses cake				395	755
Gain in per cent				168	113

Table V-B

No treatment			Complete fertilizer + no molasses cake + 100 lbs. N to No. 14 ⊕		
Tub No.	Millable cane gms.	Total weight gms.	Tub No.	Millable cane gms.	Total weight gms.
9	209	688	6	422	820
11	262	642	14⊕	3095	4875
			4	1120	2044
Total	471	1330	Total	4637	7739
Average	235	665	Average	1545	2579
Gain due to commercial fertilizer over check				1310	1914
Gain in per cent				557	288

Table V-C

No treatment			Complete fertilizer + molasses cake 20 T.P.A. + 100 lbs. N to No 7 ⊕		
Tub No.	Millable cane gms.	Total weight gms.	Tub No.	Millable cane gms.	Total weight gms.
9	209	688	5	1624	2807
11	262	642	7⊕	5122	7855
			12	2592	4014
Total	471	1330	Total	9338	14,676
Average	235	665	Average	3113	4892
Gain due to commercial fertilizer + 20 T.P.A. molasses cake				2878	4227
Gain in per cent				1224.6	636

Summary of Tables V-A, V-B, V-C

Gain of 20 T.P.A. molasses cake over no treatment	113 per cent
Gain of commercial fertilizer (133 lbs. N, 100 lbs. P_2O_5, 100 K_2O) over no treatment	288 per cent
Gain of 20 T.P.A. molasses cake and commercial fertilizer (133 lbs. N, 100 lbs. P_2O_5, 100 lbs. K_2O) over no treatment	636 per cent

From the above we note a gain of 113 per cent for 20 T.P.A. of molasses cake over no treatment. The molasses cake used supplied 160 pounds of nitrogen, 320 pounds of phosphoric acid and 1060 pounds of potash per acre. Commercial fertilizer containing 133 pounds of nitrogen, 100 pounds of phosphoric acid and 100 pounds potash per acre produced a gain of 288 per cent over no treatment.

When both the molasses cake and the fertilizer were used the gain becomes 636 per cent, more than double the gain of either one above. Judging from the gains of each one when used alone we should get a gain of about 400 per cent when combined. Instead of that we have over 600 per cent gain, an increase of 50 per cent over what was to be expected. This would indicate that under some conditions the use of molasses or a mixture as above, is not only of direct benefit, but increases the value of the other fertilizer used. (See Fig. 2.)

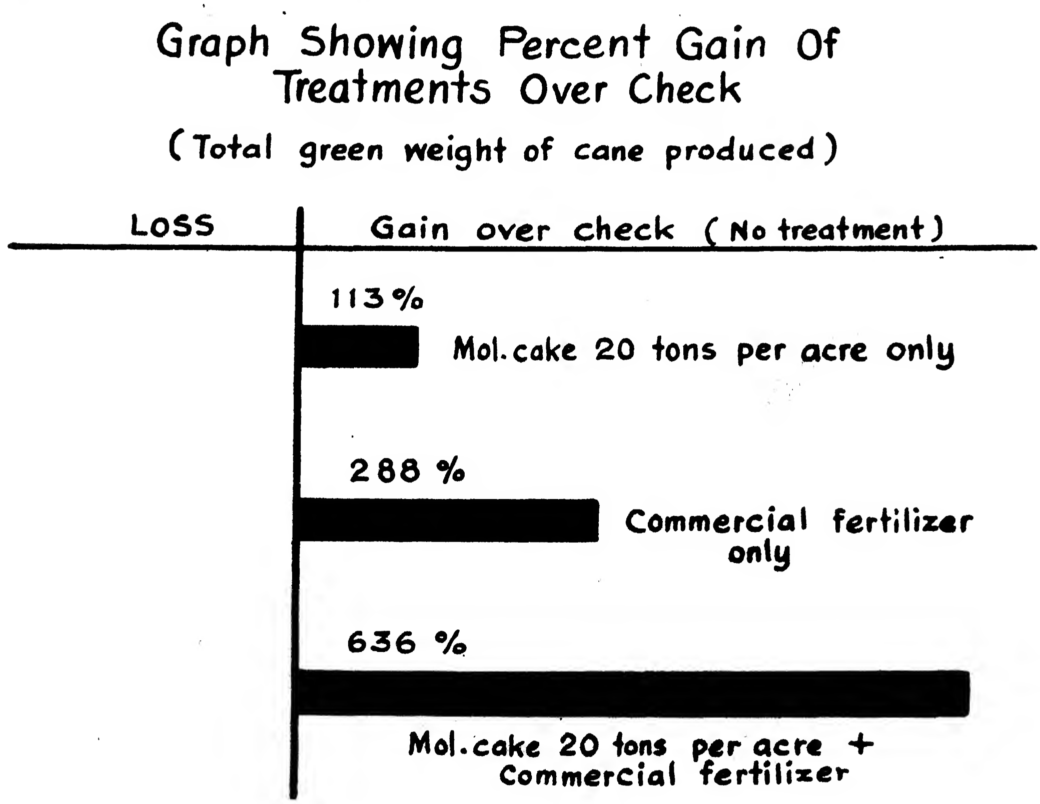


Fig. 2

Extra Nitrogen

In Table VI we show the effect of adding 100 pounds per acre of nitrogen when the cane was 3½ months of age. All other treatments were the same for the tubs compared. That is, each pair of tubs 1 and 3, 5 and 7, etc., received the same treatment except for the 100 pounds of nitrogen.

TABLE VI

No nitrogen at 3½ months			100 lbs. nitrogen at 3½ months		
Tub No.	Millable cane gms.	Total weight gms.	Tub No.	Millable cane gms.	Total weight gms.
1	239	916	3	1852	2817
5	1624	2807	7	5122	7855
6	422	820	14	3095	4875
19	544	1159	22	1543	2636
18	564	1028	20	2470	3954
21	328	779	23	3765	5607
8	1022	1924	10	3435	5921
12	2592	4014	15	9775	13157
13	1385	2314	16	5470	8274
17	1234	2297	24	4102	6486
Total	9954	18,058	Total	20,629	61582
Average	995.4	1805.8	Average	4062.9	6158.2
Gain				3067.5	4352.4
Gain in per cent..................................				308.1	241.0

The increases from this nitrogen were in all cases very large. Even tubs which had already gotten 160 pounds of nitrogen per acre from molasses cake and 100 pounds from complete fertilizer responded. See tubs Nos. 7, 14, 15 and 16.

This would indicate that the nitrogen in molasses cake is not readily available and should be supplemented with soluble forms from other fertilizer. (See Fig. 3.)

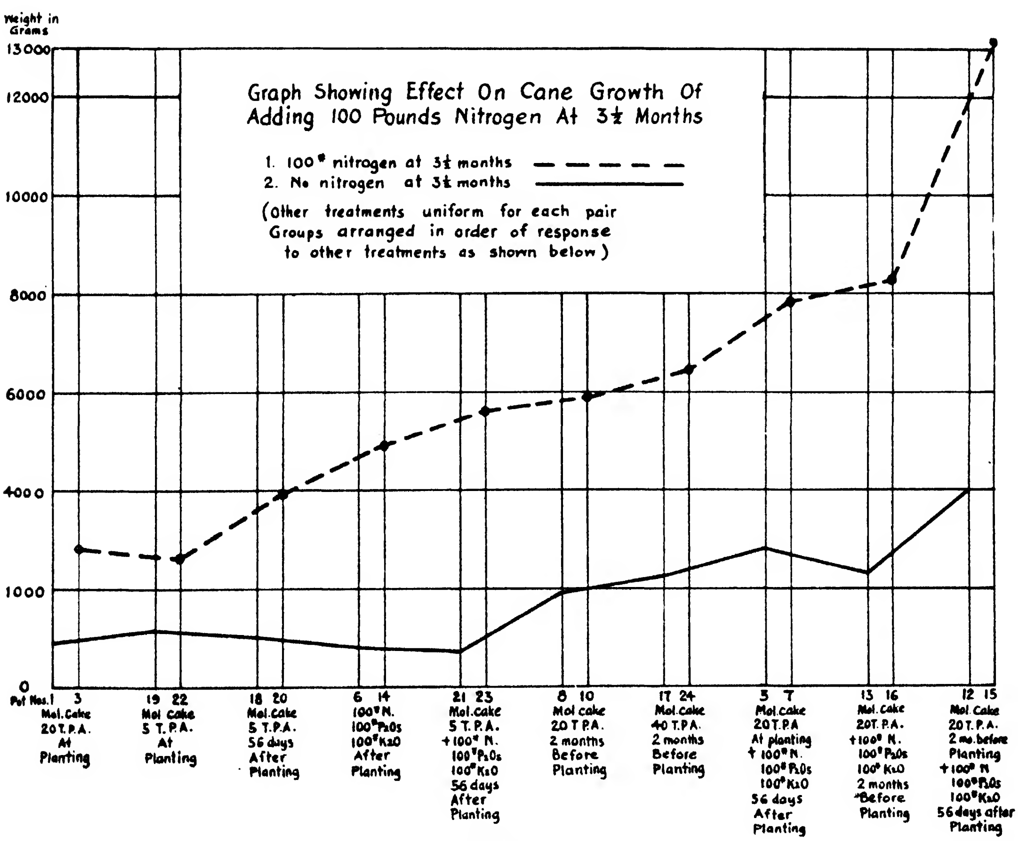


Fig. 3

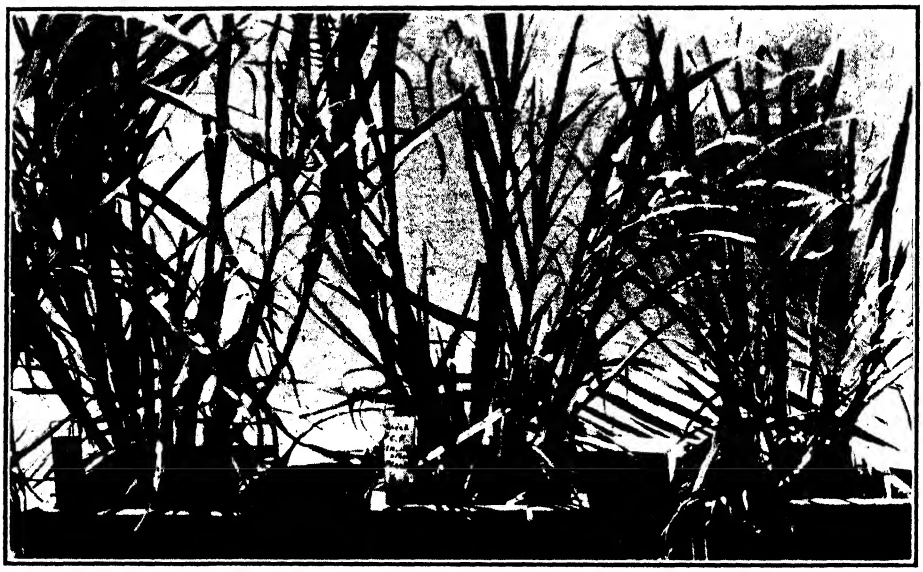


Fig. 4

No. 15

1. Molashcake 20 T. P. A. applied 2 months before planting.
2. Complete fertilizer, 100 lbs. of each element applied 56 days after planting.
3. 100 lbs. of N applied at 3½ months after planting.

Weights at 7 mos. 24 days

Millable cane .....9775 grams
Trash and Leaves..3382 grams

Total ....13,157 grams

No. 14

1. No treatment at or before planting.
2. Complete fertilizer, 100 lbs. of each element applied 56 days after planting.
3. 100 lbs. of N applied at 3½ months after planting.

Weights at 7 mos. 24 days

Millable cane .....3095 grams
Trash and leaves..1780 grams

Total ....4875 grams

No. 13

1. Molashcake 20 T. P. A. + complete fertilizer, 100 lbs. of each element applied 2 months before plantng.
2. No further treatment.

Weights at 7 mos. 24 days

Millable cane .....1385 grams
Trash and leaves.. 929 grams

Total ....2314 grams

Fig. 5

No. 12

1. Molasheake 20 T. P. A. applied 2 months before planting.
2. Complete fertilizer, 100 lbs. of each element applied at 56 days after planting.
3. No treatment at 3½ months after planting.

Weights at 7 mos. 24 days

Millable cane .....2592 grams
Trash and leaves..1422 grams

Total ....4014 grams

No. 11

Check—no treatment at any period.

Weights at 7 mos. 24 days

Millable cane ..... 262 grams
Trash and leaves.. 380 grams

Total .... 642 grams

No. 10

1. Molasheake 20 T.P.A. applied 2 months before planting.
2. No treatment at 56 days after planting.
3. 100 lbs. N at 3½ months after planting.

Weights at 7 mos. 24 days

Millable cane .....3435 grams
Trash and leaves..2486 grams

Total ....5921 grams

Soil Reaction

After the canes were harvested, the soil in each tub was sampled and the reaction determined by the chemistry department.

The results are given in Table VII.

Table VII

MOLASSES CAKE EXPERIMENT—MAKIKI EXPERIMENT 8—TREATMENTS

Tub No.	At planting time	Fertilizer applied 56 days after planting	Fertilizer applied 3½ months after planting	Soil reaction pH
2	No treatment	....	100 lb. N, 100 lb. K_2O 100 lb. P_2O_5	7.17
4	" "	....		6.95
1	Molasses cake 20 T.P.A.	....	No treatment	7.13
3	" " " "	....	100 lb. N	6.88
5	Molasses cake 20 T.P.A.	100 lb. N, 100 lb. K_2O, 100 lb. P_2O_5	No treatment	7.12
7	" " " "		100 lb. N	6.59
6	No treatment	100 lb. N, 100 lb. K_2O, 100 lb. P_2O_5	No treatment	6.44
14	" "		100 lb. N	6.59
19	Molasses cake 5 T.P.A.	....	No treatment	6.59
22	" " " "	....	100 lb. N	7.00
18	No treatment	Molasses cake 5 T.P.A.	No treatment	7.13
20	" "	" " " "	100 lb. N	7.13
21	No treatment	100 lb. N, 100 lb. K_2O, 100 lb. P_2O_5, Molasses cake 5 T.P.A.	No treatment	6.78
23	" "		100 lb. N	6.56
9	No treatment	....	No treatment	6.75
11	" "	....	100 lb. N	6.75
8	Molasses cake 20 T.P.A.	....	No treatment	6.81
10	" " " "	....	100 lb. N	7.17
12	Molasses cake 20 T.P.A.	100 lb. N, 100 lb. K_2O, 100 lb. P_2O_5	No treatment	6.75
15	" " " "		100 lb. N	6.58
13	Molasses cake 20 T.P.A. 100 lb. N, 100 lb. K_2O 100 lb. P_2O_5	....	No treatment	6.58
16		....	100 lb. N	6.32
17	Molasses cake 40 T.P.A.	....	No treatment	6.26
24	" " " "	....	100 lb. N	6.68

Although all the soils are much less acid than at the beginning of the test, there seems to be no distinction due to the various treatments.

Mr. Hansson, of the chemistry department, makes the following comment:

Twelve different treatments were tried with two tubs for each treatment. The fertilization and reaction of the soil in each tub is given in Table VII. The soil used came from our Manoa lands and had an original reaction of pH 5.3. Tubs Nos. 9 and 11, which have received no treatment of any sort, are less acid than at the start of the experiment. They now have a pH of 6.75. This would point to a possible change in reaction, as the result of irrigation with hydrant water. The hydrant water contains moderate amounts of replaceable calcium and this increase in pH would suggest that some replacement has occurred. It is also quite possible that some of the decrease in the acidity of the soil was brought about by permitting it to dry out and aereate before being used in the tubs.

Although there is some variation in the reaction of the soil in the various tubs, there appear to be no distinctive differences. The nitrogen was applied as nitrate of soda.

A Pipe Line Water Meter

A device for measuring water, which seems well adapted to local conditions, is that manufactured by the R. W. Sparling Company, of Los Angeles. The meter is adapted to pipe lines only, and is built for any pipe line, four inches or larger, and for any pressure up to 100 pounds per square inch.

Briefly, the Sparling meter consists of a propellor-shaped fan, mounted crosswise in a pipe. The fan runs on ball bearings, and drives through worm and spur gears to a registering counter. The propeller fans are constructed of cast aluminum alloy; fan shafts, cones, ball races, balls, worms and gears of Monel metal (a hard, non-corrosive alloy of copper and nickel); gear boxes, compensating gears, counters, and register boxes are of brass or bronze.

H. A. Wadsworth, of the University of Hawaii, who has seen this meter in operation, states that it is excellently constructed, is accurate, and has proved very satisfactory in California.

Waianae Company has two of these meters installed on pump discharge lines, and states that they have given satisfactory service. These meters seem particularly well adapted to small pump units, such as booster pumps with a 2 to 4 million gallon discharge, where it would not be economically profitable to install an expensive Venturi meter, but where a record of pump discharge is desired.

DATA ON SPARLING METER

	Minimum Flow		Maximum Flow		Price, F. O. B., L. A.	
Size	Sec. Ft.	Gallons/Min.	Sec. Ft.	Gallons/Min.	Regular	Heavy
4″	0.22	100	0.56	250	$ 80.00	$100.00
6″	0.28	125	1.23	550	100.00	125.00
8″	0.33	150	2.23	1,000	120.00	150.00
10″	0.39	175	3.79	1,700	140.00	175.00
12″	0.49	220	5.90	2,650	160.00	200.00
14″	0.60	270	8.47	3,800	180.00	225.00
16″	0.72	325	10.58	4,750	200.00	250.00
18″	0.96	430	13.37	6,000	220.00	275.00
20″	1.28	575	20.06	9,000	240.00	300.00
24″	1.67	750			280.00	350.00
30″	2.67	1,200			.....	425.00
36″	3.57	1,600			.....	500.00
48″	5.35	2,400			.....	650.00

H. R. S.

Fungicidal Dust Tests Against Eye Spot During the 1927-1928 Eye Spot Season*

By J. P. Martin

The results from the experimental research conducted with fungicidal dusts against eye spot during the 1926-1927 eye spot season were sufficiently encouraging to warrant further studies the following season. Two points were established: First, the addition of potassium permanganate as an oxidizing agent at the rate of one per cent to dusting sulphur, gave much better control of the disease when applied at weekly intervals than had been obtained before. Secondly, it was found that when calcium hydrate was used as a carrier the disease increased rapidly and the eye spot counts were greater than those from the check plots or plots receiving no dust treatment. Apparently the calcium hydrate saponified to a large extent the wax on the surface of the cane leaf, thus making it an easy matter for the fungus to penetrate the young cane leaf. It was necessary to discontinue the use of several dusts with a lime base long before the peak of the eye spot season was reached because of the sudden increase of eye spot.

With the above information it was decided to use a fine grade of dusting sulphur as the carrier for all dusts. Since sulphur plus one per cent of potassium permanganate gave such a good control of the disease, it was planned to add other oxidizing agents to sulphur, such as manganese dioxide and lead dioxide.

In fungicidal work "stickers" are often added to dusts and sprays in order that the dusts or liquid sprays may adhere better to the foliage. Upon this basis dextrin and gum tragacanth were added at the rate of one per cent to sulphur plus one per cent of potassium permanganate.

With the above knowledge the following dusts were planned by H. A. Lee and the writer to be tested during the 1927-1928 eye spot season:

Dust No.	Dust Letter	Mixture of Dust	
1	A	Sulphur	
2	B	"	plus 5% $KMnO_4$
3	C	"	" 1% "
4	D	"	" 5% MnO_2
5	E	"	" 5% PbO_2
6	F	"	" 1% $KMnO_4$ plus 4% MnO_2
7	G	"	" 1% " " 1% Dextrin
8	H	"	" 1% " + 1% gum tragacanth
2	I	"	" 5% "
3	J	"	" 1% "

In Field Kemoo 1 of the Waialua Agricultural Company, Ltd., which contained young plant H 109 cane, 42 ten-line plots were staked and labeled according to the plan as shown in Fig. 1. Dusts A, B, D, E and F were applied every two weeks,

* Reprinted from last number to include illustrations omitted in that issue.

FUNGICIDAL DUSTS IN RELATION TO EYE SPOT

W. A. Co. Ltd., Field Kemoo 1; 1st Ratoon, H 109 Cane

6 X Plots	Controls, No Treatment		
6 A ..	Sulfur		
6 B ..	..	plus	5% $KMnO_4$
6 D ..	..	..	5% MnO_2
6 E ..	..	..	5% PbO_2
6 F ..	..	..	1% $KMnO_4$ plus 4% MnO_2
6 I ..	..	..	5% $KMnO_4$

Dusts A, B, D, E and F were applied every two weeks.
Dust I was applied weekly.
First Application of all Dusts October 28, 1927

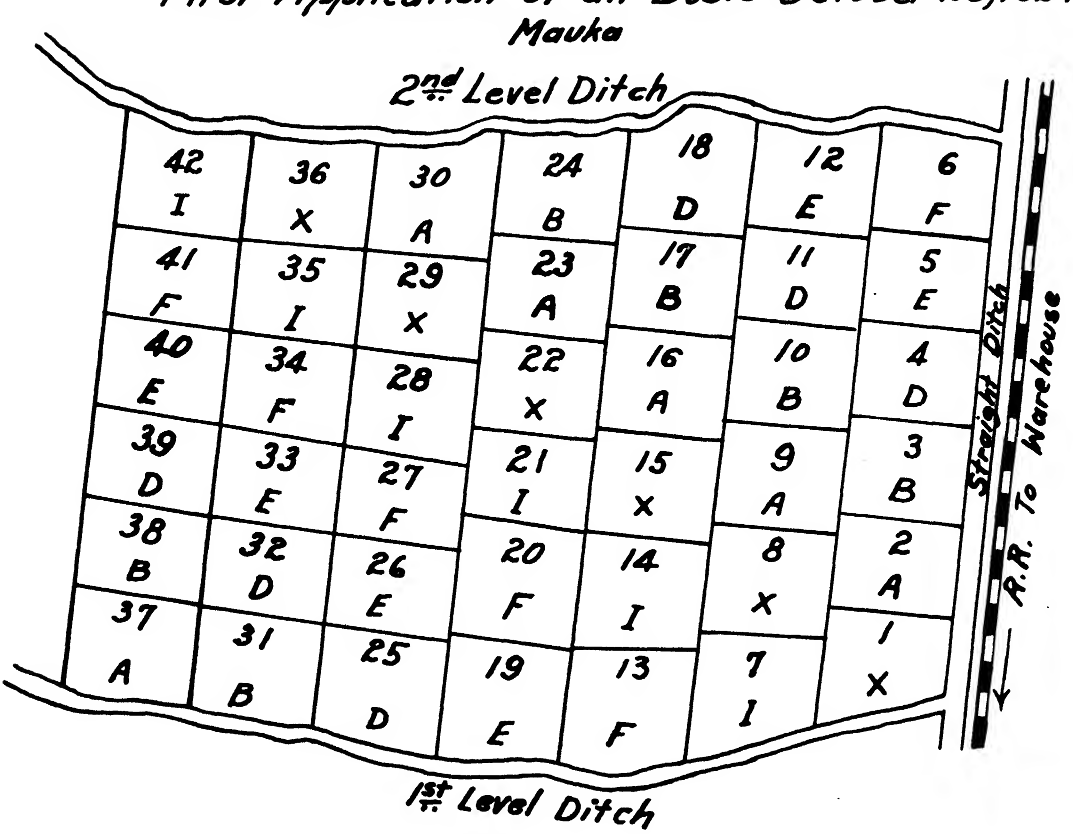


Fig. 1

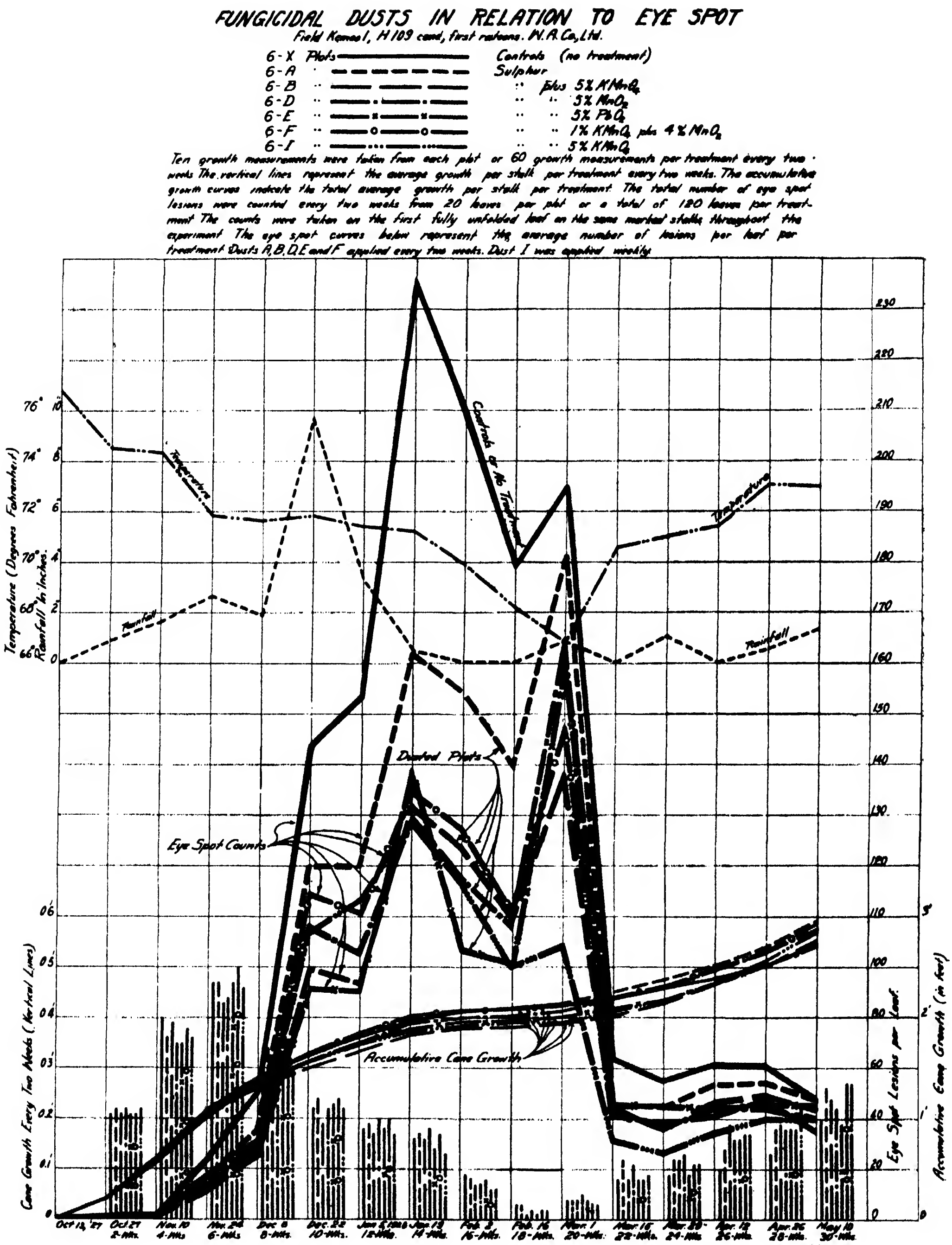

FUNGICIDAL DUSTS IN RELATION TO EYE SPOT
Field Kemoo I, H 109 cane, first ratoons. W. A. Co., Ltd.
6-X Plots Controls (no treatment)
6-A " Sulphur
6-B " " plus 5% $KMnO_4$
6-D " " " 5% MnO_2
6-E " " " 5% PbO_2
6-F " " " 1% $KMnO_4$ plus 4% MnO_2
6-I " " " 5% $KMnO_4$
Ten growth measurements were taken from each plot or 60 growth measurements per treatment every two weeks. The vertical lines represent the average growth per stalk per treatment every two weeks. The accumulative growth curves indicate the total average growth per stalk per treatment. The total number of eye spot lesions were counted every two weeks from 20 leaves per plot or a total of 120 leaves per treatment. The counts were taken on the first fully unfolded leaf on the same marked stalks throughout the experiment. The eye spot curves below represent the average number of lesions per leaf per treatment. Dusts A, B, D, E and F applied every two weeks. Dust I was applied weekly.
Temperature (Degrees Fahrenheit)
Rainfall in Inches
Cane Growth Every Two Weeks (Vertical Lines)
Eye Spot Lesions per Leaf
Accumulative Cane Growth (in feet)
Controls or No Treatment
Temperature
Rainfall
Dusted Plots
Eye Spot Counts
Accumulative Cane Growth
Oct 13, '27
Oct 27 2-Wks.
Nov. 10 4-Wks
Nov. 24 6-Wks
Dec 8 8-Wks.
Dec. 22 10-Wks.
Jan 5, 1928 12-Wks.
Jan 19 14-Wks.
Feb. 2 16-Wks.
Feb. 16 18-Wks.
Mar. 1 20-Wks.
Mar. 15 22-Wks.
Mar. 29 24-Wks.
Apr. 12 26-Wks.
Apr. 26 28-Wks.
May 10 30-Wks.
J. P. M. 6-28.

Fig. 2

while Dust I was applied weekly, beginning October 28, 1927. There were six repetitions of each fungicidal dust treatment and six check plots that received no treatment. No further dust applications were applied after February 9, 1928, which was after the peak of the eye spot season.

Eye spot counts were taken in each plot from 20 leaves, or the total number of lesions from 120 leaves were counted every two weeks from each treatment. In every case eye spot counts were taken from the first fully unfolded leaf on the same marked stalks throughout the experiment. The average number of eye spot lesions per leaf from each treatment is shown in Fig. 2 by the heavy curves labeled eye spot counts.

The word *control* as used throughout this article signifies the difference for each treatment between the average number of lesions or infections per leaf of the treated and of the non-treated plots. The difference is secured by comparing quantitative calculations as explained in the preceding paragraph. This is not to be confused with the more practical definition of the word *control* as applied to plant diseases which compares the increase in yield of any crop due to special treatment with the yield obtained from similar plots or areas not receiving special treatment.

The object of applying fungicidal dusts to cane is to have a coating of the dust on the leaves at all times during the winter months so that the spores of the fungus upon germination are immediately killed as soon as they come in contact with the dust, thus preventing their entrance to the leaf. Once the fungus has penetrated the leaf a dust or spray that would be toxic to the development of the organism within the leaf tissue would also be very injurious to the cane plant itself. To maintain such a coating of dust on the cane foliage during the rainy season it would be necessary to apply such dusts to the susceptible areas from two to three times a week. These numerous applications would be prohibitive on a plantation basis because of the expense that would be involved.

The damage on cane leaves resulting from eye spot is not in direct proportion to the number of infections. The seriousness of the disease depends largely on the location of the infections in the leaf itself. From each infection large runners or streaks develop, extending from the initial infection, up the vascular system, to the edge of the leaf. The tissue killed by the so-called runner is oftentimes a hundred times greater than the tissue killed by the primary infection. If ten lesions occur on a single leaf so that ten separate runners are formed, the damage is much greater than if ten lesions occur on another leaf with only five runners formed, due to the fact that certain of the infections fall within the streaks extending from lower infections on the leaf. Therefore, 50 lesions may produce the same amount of damage as 100 lesions.

Ten growth measurements were taken at two-week intervals from each plot, and the average growth per stalk per treatment is presented in Fig. 2 by the vertical lines. The accumulative cane growth from each treatment is also presented in Fig. 2 for the duration of the experiment, which was thirty-eight weeks.

The peak of the eye spot season occurred on January 19, 1928, and the per cent of control from each dust at that date was as follows:

Dust	Per Cent Control
A	31
B	44
D	45
E	41
F	43
I	46

A control with each fungicidal dust was maintained during the eye spot season, as shown in Fig. 2. On January 19, 1928, the lesions per leaf in the dusted plots varied from 128 to 161 as compared to 235 per leaf on the plots receiving no dust treatment. Field observations at this date showed that all plots were badly affected with eye spot, but a fair control was evident on the dusted plots.

The addition of "stickers," such as dextrin and gum tragacanth, did not give an added control of the disease when compared to similar dusts without the "stickers."

In Field Valley 3 of the Waialua Agricultural Company, Ltd., which contained young plant H 109 cane, the remainder of the dusts listed were tested, namely, dusts C, G, H and J, including dust A. In this experiment 42 ten-line plots were staked and labeled according to the plan as shown in Fig. 3. There were seven repetitions of each treatment, and seven check plots which received no dust applications.

Eye spot counts were taken in each plot from 20 leaves, or the total number of lesions from 140 leaves were counted every two weeks from each treatment. The counts were taken from the first fully unfolded leaf on the same marked stalks throughout the experiment. The results of the various fungicidal dusts A, C, G, H and J, in relation to the control of the disease, are presented in Fig. 4 by the heavy curves labeled eye spot counts.

Ten growth measurements were taken at two-week intervals from each plot and the effect of each dust treatment on the cane growth is shown in Fig. 4, both by the vertical growth curves and the accumulative growth curves.

As illustrated in Fig. 4, a definite control was secured with each fungicidal dust, but no one dust showed exceptional merit. The eye spot counts started to increase rapidly about November 29, 1927, and the peak of the season was reached February 21, 1928. Two other smaller peaks occurred on April 2 and May 1, but the effects of these were negligible. The control from each dust at the peak of the eye spot season, February 21, 1928, was as follows:

Dust	Per Cent Control
J	62
A	55
C	53
G	47
H	47

A decided decrease in the accumulative cane growth was evident on the check plots when compared to the accumulative cane growth from the dusted plots as brought out in Fig. 4. The cane growth on the dusted plots at all times was

FUNGICIDAL DUSTS IN RELATION TO EYE SPOT

W. A. Co. Ltd., Field Valley 3, Plant H109 Cane

7 X Plots	Controls No Treatment	
7 A "	Sulfur	
7 C "	" plus 1% $KMnO_4$	
7 G "	" " 1% " plus 1% Dextrin	
7 H "	" " 1% " " 1%	Gum Tragacanth
7 J "	" " 1% "	

Dusts A, C, G, and H were applied every two weeks

Dust J was applied weekly

First Application of all dusts, Nov. 2, 1927

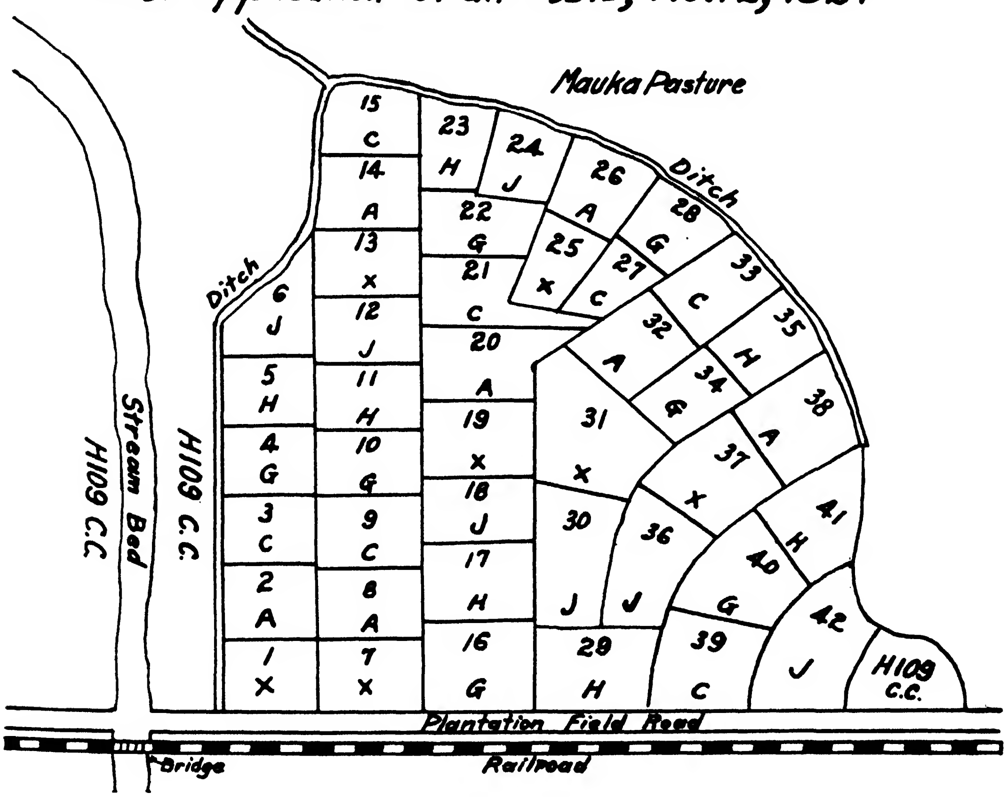


Fig. 3

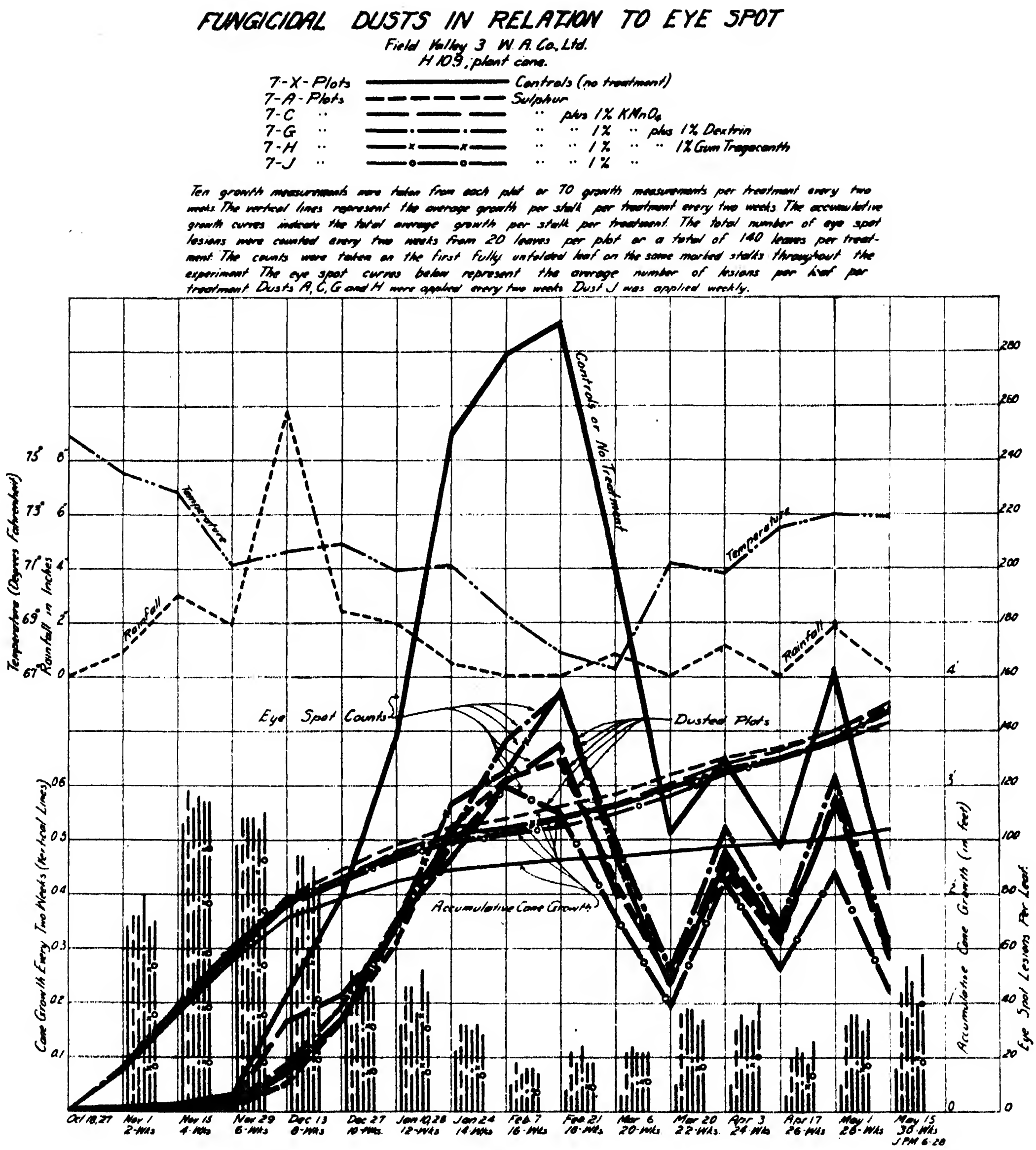

FUNGICIDAL DUSTS IN RELATION TO EYE SPOT
Field Valley 3 W. A. Co. Ltd.
H 109, plant cane.
7-X-Plots Controls (no treatment)
7-A-Plots Sulphur
7-C " plus 1% KMnO4
7-G " " 1% " plus 1% Dextrin
7-H " " 1% " " 1% Gum Tragacanth
7-J " " 1% "
Ten growth measurements were taken from each plot or 70 growth measurements per treatment every two weeks. The vertical lines represent the average growth per stalk per treatment every two weeks. The accumulative growth curves indicate the total average growth per stalk per treatment. The total number of eye spot lesions were counted every two weeks from 20 leaves per plot or a total of 140 leaves per treatment. The counts were taken on the first fully unfolded leaf on the same marked stalks throughout the experiment. The eye spot curves below represent the average number of lesions per leaf per treatment. Dusts A, C, G and H were applied every two weeks. Dust J was applied weekly.
Controls or No Treatment
Temperature
Rainfall
Eye Spot Counts
Dusted Plots
Accumulative Cane Growth
Temperature (Degrees Fahrenheit)
Rainfall in Inches
Cane Growth Every Two Weeks (Vertical Lines)
Accumulative Cane Growth (in feet)
Eye Spot Lesions Per Leaf
Oct 18, 27
Nov 1 2-Wks
Nov 15 4-Wks
Nov 29 6-Wks
Dec 13 8-Wks
Dec 27 10-Wks
Jan 10, 28 12-Wks
Jan 24 14-Wks
Feb 7 16-Wks
Feb 21 18-Wks
Mar 6 20-Wks
Mar 20 22-Wks
Apr 3 24-Wks
Apr 17 26-Wks
May 1 28-Wks
May 15 30-Wks
JPM 6-28

Fig. 4

practically the same. At the end of the experiment, May, 1928, a difference of one foot of cane growth was observed between the dusted plots and non-dusted plots. This difference was due to the high mortality of individual stalks resulting from top rot in the non-dusted plots.

There appears to have been a very good control from all dusts when expressd in terms of per cent. When leaves average 100 or more eye spot lesions per leaf, another 100 lesions does not add greatly to the present damage to the leaf, but there is a great difference in the control as expressed in per cent. Even though a control varying from 47 to 62 per cent was obtained with the various dusts, it would be necessary to keep the average number of lesions or infections below 60 per leaf in the experimental tests before the dust could be used on a commercial basis.

Of the dusts tested, sulphur plus one per cent of potassium permanganate, when applied at weekly intervals, gave the best control of the disease. This particular dust was also the outstanding one during the preceding eye spot season, and at that time an 89 per cent control was secured.

During the winter months frequent rains are common. In view of the experimental evidence it is necessary to apply the dusts at weekly intervals rather than at two-week intervals because a great deal of dust is washed from the foliage by the rains. It is impossible to apply the dusts at certain periods for two weeks at a time, because of daily showers or rains. Under these conditions the fungus spreads rapidly and the efficacy of any dust against eye spot applied during the winter months depends largely on the rainfall.

In Figs. 2 and 4 the rainfall and temperature are plotted every two weeks for the duration of the experiment, and a direct correlation is observed between temperature and cane growth, and also between rainfall and eye spot counts. With a decrease in temperature there is a decrease in cane growth, and with an increase in temperature there is a corresponding increase in cane growth. With an increase of rainfall there is a marked increase in the eye spot counts, and each eye spot peak, whether large or small, is accompanied by an increase in rainfall. These correlations are brought out by referring to Figs. 2 and 4.

Summary

1. Sulphur plus one per cent of potassium permanganate gave the best control of all the dusts tested. This particular dust was the outstanding dust in last year's experimental work (1926-1927).

2. The interval between two-week applications was too great during the rainy weather. Weekly applications of fungicidal dusts should be maintained during the winter months.

3. The efficacy of any dust against eye spot depends largely on the amount of rainfall and the frequency with which the dust is applied during the very wet weather.

4. Before a dust is tested out on a commercial basis, the average eye spot lesions per leaf should be kept below 60 at all times in preliminary experimental test plots.

Fig. 1. Vineyard Street Nursery. View along the lower terrace, showing seedling trees growing in the partial shade of trees planted out in the ground. On the extreme right may be seen the trunk of a Charcoal tree, *Trema orientalis*, which is six years old. It is twenty inches in diameter three feet from the ground. Photo by E. L. Caum.

5. There was a direct correlation between temperature and cane growth; with a decrease in temperature there was a decrease in cane growth, and with an increase in temperature there was an increase in cane growth.

6. There was also a direct correlation between rainfall and eye spot counts; with every sudden increase in eye spot counts there was a corresponding increase in rainfall slightly preceding the increase in the eye spot counts.

Ten Years in Hawaiian Forestry

By H. L. Lyon

The department of botany and forestry of the Experiment Station, H. S. P. A., was established in 1918, and has now existed through a period of ten years. The work of this department has been recorded in monthly and annual reports, while special reports on the separate projects under way have been issued from time to time. An exhaustive report, reciting all the details of the numerous projects, propositions and negotiations which have engaged the attention of the department during the past ten years would, therefore, be but needless repetition of facts already on record. There are, however, matters pertaining to the organization and equipment of the department, and to certain phases of its activities, which have not been adequately recorded in any previous report. There are also cumulative results not apparent from day to day, or even from year to year, but which are quite evident when one scans a ten-year period. To complete the records of the department and otherwise round out its history is our excuse for preparing the present report.

When we began to study the local forestry problems and lay out a program for the department of botany and forestry we realized that our efforts along certain lines might easily be misconstrued, and provoke a merited opposition which would at once defeat our aims; for we were about to invade a field of work already wholly under the control of a government bureau, the Board of Commissioners of Agriculture and Forestry, which employed a forestry staff. Consequently from the very beginning we have tried, as representatives of the H. S. P. A., to maintain at all times the attitude of interested citizens and taxpayers, and not to exceed in any way the privileges of such in extending the scope of our departmental activities. We have undertaken extensive investigations and experiments in forestry, we have offered suggestions and assistance to the officers of the bureau, and we have argued the cause of forestry in public meetings and in the press, but we have carefully avoided any word or act that might be construed as an effort on our part to dictate or execute a Territorial forestry policy.

When we first entered forestry work the Territorial Forester was greatly handicapped by lack of competent assistants and dearth of funds for carrying on his work. At the outset it was evident that we could do much for the cause of

Fig. 2. *Ficus variegata,* a fig from Java. The specimen here pictured is growing in the Vineyard Street nursery. It was five years old when photographed. This tree is deciduous and remains leafless for a short period each year.

Fig. 3. *Ficus variegata.* Trunk of the specimen shown in Fig. 2 as seen close up. The figs are produced in abundance on short branches emanating from leafless portions of the trunk and larger branches.

Hawaiian forestry by assisting the Forester in his field work, and this has been our constant endeavor. In all matters pertaining to the administration of forest reserves, we have at all times subordinated our personnel to the Territorial Forester. This relation has been officially sanctioned by the Board of Agriculture and Forestry, which has commissioned each of our men an honorary forestry officer. On Hawaii and Kauai the administration of all government forestry projects has in recent years been placed in the hands of men drawn from our department, who now hold salaried positions on the staff of the Territorial Forester. We believe that an examination of forestry operations in Hawaii during the past ten years will show such complete accord between our department and that of the Board of Commissioners of Agriculture and Forestry as may be cited as an example of real cooperation.

The Reforestation Problem as We Found It

It has been recognized by all students of the Hawaiian flora that the indigenous trees and shrubs which constitute the rain forests on our watersheds are in a very delicate state of health, and that the slightest interference from man or his domestic animals so disturbs their balance that a rapid deterioration sets in which soon terminates in the death of the majority of the native plants. Certain pernicious shrubs, weeds and grasses which have been introduced into these islands, intentionally or inadvertently by man, find local conditions well suited to their requirements. They spread rapidly and always stand ready to occupy immediately any area vacated by the native plants. As a consequence, we see the native forests rapidly disappearing from our watersheds and their places being taken by open grass land or weedy scrub. The nucleus of the forces which brought about the destruction of the native forests and their replacement by foreign plants was introduced into this environment over a hundred years ago with the introduction of the white man's favorite domestic animals, the cow and the horse. These forces grew rapidly through multiplication and additions of their kind, while new forces of a deleterious nature were added with increasing frequency until there was soon arrayed against the native forests an irresistible strength before which they retreated with ever increasing rapidity. The speed with which a native forest would die out as a result of invasion by stock soon attracted the attention of naturalists, and as early as 1856 an anonymous author called public attention to this fact and its ultimate result in a paper published in a local magazine. It was many years later, however, before the Hawaiian government actually recognized the need of a forest conservation policy and called upon competent men to study the local forests and devise means of rehabilitating them.

The first attempts at reforestation in Hawaii were very naturally made with native trees. Repeated trials demonstrated, however, that the Ohia tree, which is the main constituent of all Hawaiian forests, would not lend itself to artificial propagation, and in fact could not be used successfully in reforestation. The Koa tree could be grown on limited areas only, but experience soon demonstrated that planted Koa trees were as a rule short lived. The foresters were eventually forced to the conclusion that the only means of reforesting our watersheds would

Fig. 4. Vineyard Street Nursery. View across the second terrace, showing at the left the trunk of a Yokewood tree, *Catalpa longissima*. In eight years this tree has attained a height of sixty-five feet. Photo by E. L. Caum.

be to employ exotics. The marvelous success obtained with such trees as Eucalyptus, Ironwood, Wattles, Monterey Cypress and Silver Oak proved conclusively that there were foreign trees which would grow and produce a forest cover in the very soils where the native trees failed to flourish. The results obtained in forest building with the trees named above, however, soon showed that these particular trees, in pure cultures of each variety or in mixed groves, would not produce an ideal water-conserving forest cover such as we desired to create on our watersheds, and it was obvious that other exotic trees of a more serviceable nature were urgently needed. Hawaiian forestry had just reached this stage in its development ten years ago when we were called upon to organize a forestry department to cooperate with the officers of the Board of Agriculture and Forestry in the solving of Hawaii's forest problems.

Upon analyzing the local forestry problems as best we could from the available evidence, we found that in addition to attacking some of these under the supervision of the Board of Agriculture and Forestry, our department could contribute much towards the solution of others by concentrating its attention upon the introduction of new trees and shrubs from foreign countries, testing these out under local conditions, and propagating those which proved most suitable for inclusion in the new forests which we must build on our watersheds. This was a strictly botanical undertaking which could be successfully executed by trained botanists only, and as the Board of Agriculture and Forestry had none such on their staff, it seemed quite appropriate that our department should take the initiative in this particular phase of forestry work and make it one of its chief endeavors.

When considering foreign trees for use in Hawaiian forestry, we realized that there already existed in this Territory a very large exotic flora which had resulted from the efforts of innumerable plant lovers who, in times past, had spent much effort and money in introducing plants to beautify their gardens. There were no records available whereby we could learn to what extent, if any, these plants had been tested out locally for forestry purposes, and it seemed certain that much valuable evidence and some valuable material could very soon be obtained if we tried out all exotics present in the Territory, along with such new ones as we were able to introduce. From those already present we could at once secure an abundance of seed and thus provide ourselves with ample material for immediate experimentation. The results obtained with some of the foreign trees already established in the Territory, but entirely neglected as possible components of the forests which we wished to build, have more than justified the efforts devoted to trees of this nature. At the present time it looks as though several of the trees best suited for planting on our watersheds are species of which specimens have been present in this Territory for many years, but whose potentialities were not recognized because they had not been tested out for forestry purposes. Trees of this nature will receive special mention in a later paragraph of the present report.

Vineyard Street Nursery

In order to engage in the growing and testing of exotic trees for forestry purposes, the first requisite of our department was an appropriate nursery in which

Fig. 5. Manoa Arboretum. The upper lands of Haukuiu assigned to the arboretum include only sharp ridges with very steep slopes which lean up against the Manoa cliffs.

to plant the seeds of the various trees to be tested, and to rear the young seedlings up to an appropriate size for planting out in the field. Our interest in plant life had gained for us favorable consideration from Mrs. Mary E. Foster, who had acquired the garden founded by Dr. Hillebrand and, during her thirty years of possession, had not only preserved it carefully but had added adjoining land and embellished it throughout with many new plants. Learning that I was seeking an appropriate site for a nursery, Mrs. Foster very kindly offered for the purpose a very desirable piece of land adjoining her garden. It was in the center of a block, but she arranged to include with it two other pieces of property which gave us an entrance on Vineyard street, and a total area of 1.95 acres. We took possession under a personal agreement between Mrs. Foster and myself, but at a later date this was converted, with some modifications, into a formal lease by Mrs. Foster to the H. S. P. A. This first lease was for a period of ten years from the first day of January, 1919. In 1927 a new lease was obtained, including an additional piece of property, bringing the total area up to 2.522 acres. The second lease was for a period of twelve years from September 1, 1927. There were certain stipulations in the original agreement which do not appear in the leases. Some of these pertain to operations on the leased land, and others to work to be done in the old garden. Those pertaining to the leased land have been and are being carried out to the last detail, but a change in the management of Mrs. Foster's garden has made it impossible for us to execute all of the tasks which we were prepared to undertake to preserve and improve the older garden. The nursery site lies just makai of Mrs. Foster's garden, joining the same along a boundary of 304 feet. In times past it had been used as a vegetable garden, but when we took it over it had not been cultivated for some twenty years or more. This land carried one large clump of edible bamboo and a few sizeable trees, but was otherwise covered throughout with one solid thicket of Haole Koa and other weedy leguminous shrubs. It lay on a gentle slope, the mauka edge being some ten feet higher than the makai boundary. We agreed that while developing this as a nursery we would plant it up with new trees and shrubs in so far as it was possible to do so and not interfere with the area available for our work, or render it unsuitable for nursery purposes. The lower portion of Mrs. Foster's old garden is terraced, and in laying out the nursery we first terraced it in a manner corresponding with that obtaining in the garden above. We have also set out in the ground numerous trees and shrubs, until at the present time one portion of the nursery is a veritable forest. These trees occupy little ground space, however, and they afford the partial shade in which young seedlings grow to best advantage. Successful nursery practice requires that we keep a certain portion of our space quite open so that we can bring our seedlings out into full sunlight and harden them off before they are sent out for planting in the field. Most tree seedlings thrive best in their early stages if grown in partial shade, but such seedlings should be gradually brought out into full sunlight, for a quick transfer from constant shade to full exposure often results in the death of the seedling. We have endeavored to so plant up our nursery as to provide ideal conditions for handling seedlings and getting them into proper condition for transfer to the open ground

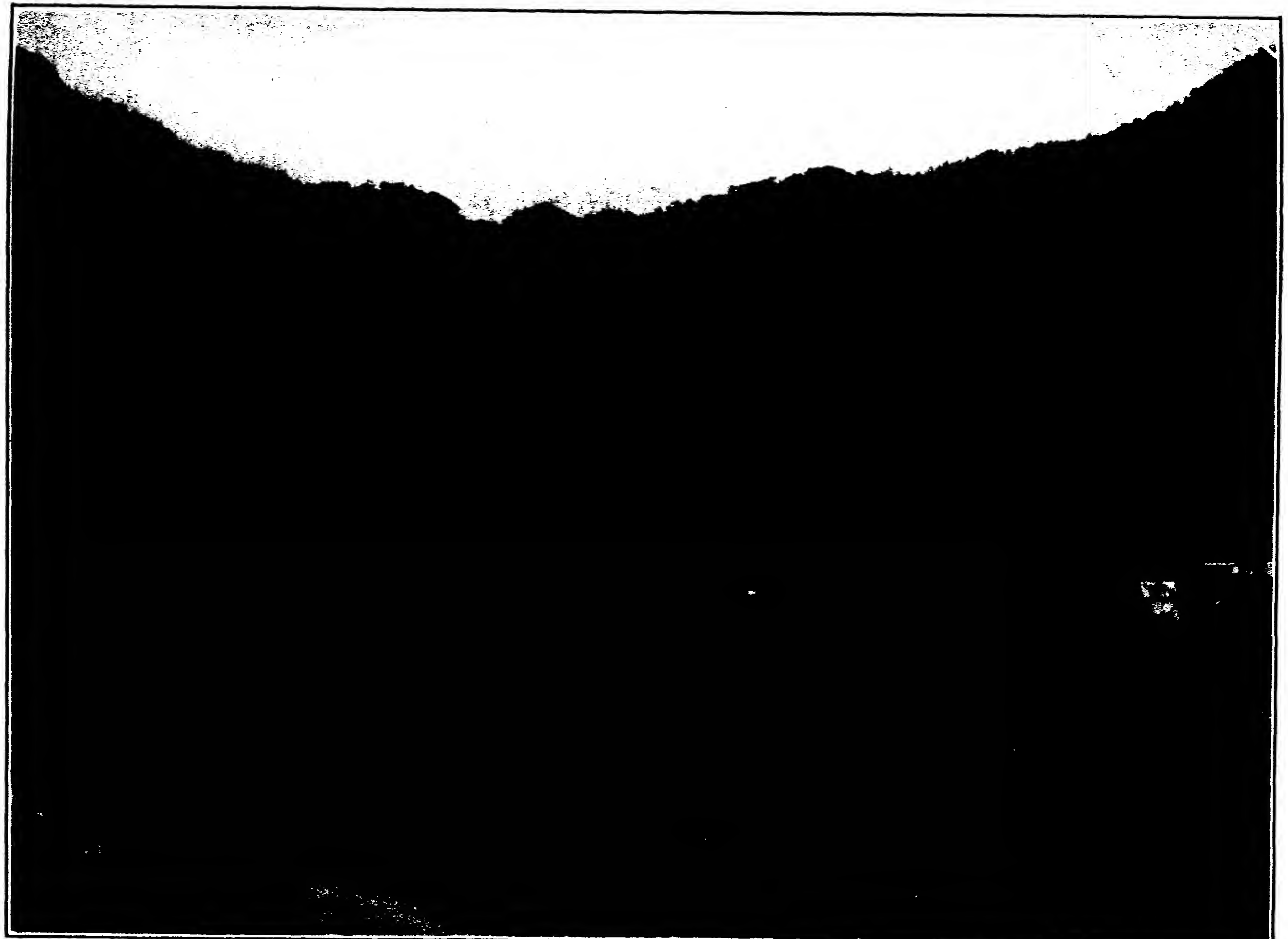


Fig. 6. Manoa Arboretum. A view up Aihualama valley with Haukulu on the left and Aihualama on the right. The brink of the pali in the background is the boundary between these lands and Kaakaukukui. A trail up the pali in Aihualama reaches Pauoa Flats or Kapukaawapuhi at about the center of the picture.

in various parts of these islands. The trees planted in the nursery have not only fulfilled our agreement with Mrs. Foster and supplied the necessary shade, but have also been an important source of seed supply. Naturally we selected some of the rarest and most valuable trees for planting in this situation, as here we could give them the most constant attention. Then too, the nursery site, protected on the mauka side by the big trees in Mrs. Foster's garden, affords veritable hothouse conditions, and consequently plants grow there as they would grow nowhere else on the island. Among the trees of note is a rare *Cassia* from Siam, and another from Central America. A Yokewood from Jamaica has attained a height of sixty-five feet in eight years, and has supplied us with an abundance of seed since it was one year old. It is the parent of a rapidly increasing and widely distributed progeny. A Chaulmoogra from Siam was the first tree of its kind to produce fruit in Hawaii, and its seedlings are already being distributed. The only clump of giant bamboo in the city occupies a central position in the nursery. It was grown from seed obtained in Ceylon. It is rapidly attaining such dimensions that it will be necessary to dig it out, and we expect to obtain from this one clump sufficient planting material to start some fifty plants in other situations. A specimen of the Charcoal tree from India has in six years' time attained the height of fifty-eight feet, with a trunk twenty inches in diameter three feet from the ground. A *Caesalpinia,* grown from seed obtained from Brazil in 1920, has reached a height of forty-five feet, a spread of sixty feet, and has a trunk twenty-five inches in diameter three feet from the ground. The only specimen of the Spanish Cedar in the Territory which has reached flowering size is located in the nursery. This tree yields a scented wood used in Cuba for the manufacture of cigar boxes. The two specimens of the Buttercup tree in the nursery supply all the seed we require for the propagation of this useful and ornamental tree. A tree of *Baryxylum africanum,* near the center of the nursery, is the only fruiting specimen of its kind in the Territory.

When we conducted our first negotiations with Mrs. Foster, looking towards the location of the nursery on her property, one of the conditions mutually agreed upon provided that we should at all times have access to her garden and be privileged to collect therefrom seeds of any or all of the rare trees growing therein. This privilege has been of great value to us as we have secured from her garden seeds of several trees which have proven of much importance in our forestry work. Among these the Queensland Kauri pine should receive special mention, for from the single magnificent specimen in her garden, we have secured the seed from which we have grown innumerable seedlings of this remarkable timber tree and distributed them to all parts of these islands.

In organizing and equipping our forest nursery in Honolulu we proceeded on the assumption that we would be permitted to ship young seedling trees in the boxes of soil in which they had been grown, to any of the other islands. This procedure was being followed at the nursery of the Board of Agriculture and Forestry. Before the seedlings from our first sowings had reached suitable size for shipment, however, the Board of Agriculture and Forestry enacted a new rule forbidding the shipment of plants in soil from Oahu to the other islands. This

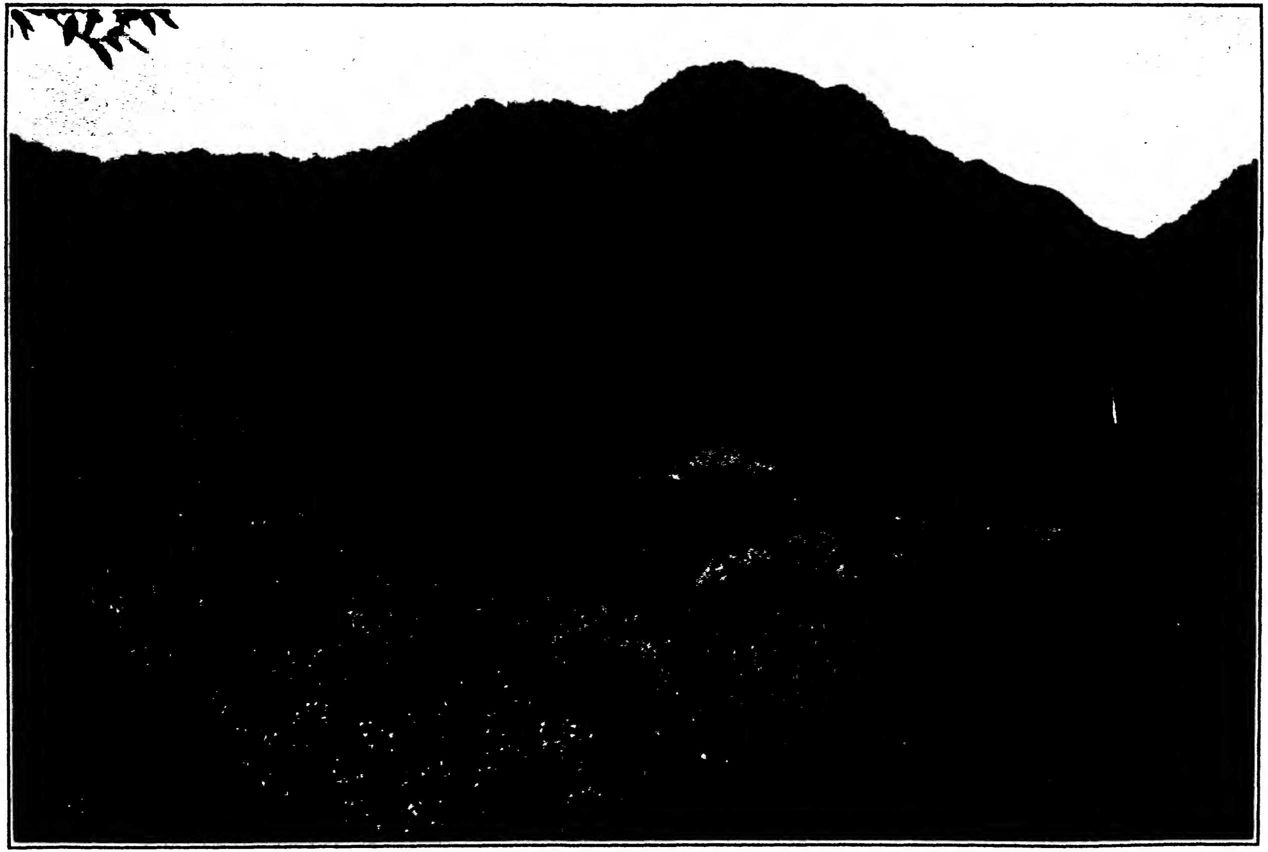


Fig. 7. Manoa Arboretum. Upper portion of Aihualama as seen from Haukulu. This picture and that reproduced as Fig. 8 were taken at the same time and from the same setting, the camera being swung on the tripod between exposures. The high peak in the background is Kaumuhonu, which constitutes the mauka corner of the arboretum. Photos by E. L. Caum.

rule stopped shipments from their own nursery as well as from all other nurseries on Oahu. It was deemed necessary in order to prevent the transfer to other islands of a troublesome soil-dwelling insect that had become established on Oahu. This sudden and unexpected ruling of the Board seemed destined for a time to prevent the functioning of our nursery as a source for the general distribution of tree seedlings, but we soon devised a method of shipping the young trees in wet sphagnum moss, which proved quite as satisfactory as sending them forward in soil. To accomplish this successfully, however, we had to grow our seedlings to a much larger size, and this required that they be transplanted at least once in the nursery before being shipped. This increased many times the nursery cost of growing seedlings, and at the same time reduced in like proportion our chance of recording big shipments from our nursery. When seedlings are sent out in the flats in which the seed was sown, it is often possible to ship one box 4″x13″x18″ and truthfully record that you have shipped from your nursery a thousand or more seedlings. In order to get the seedlings from such a flat into suitable size for shipment from our nursery, we have to transplant them into at least fifteen flats of the same size, and hold them therein for from three to six months, during which time there will be some, and perhaps numerous, casualties. When we prepare these seedlings for shipment, the soil is washed from their roots, and they are done up in bundles of a given number, with their roots embedded in wet moss. A thousand seedlings so prepared for shipment occupy considerable space, the actual space required, of course, depending upon the size to which the seedlings have been grown, and the character of their foliage. Seedlings grown to a proper size for planting out before they leave the nursery and then shipped in moss, always receive prompt attention at their destination, and the number which actually get into the ground is nearly, or quite, 100 per cent of those leaving the nursery. When small seedlings are sent out from the nursery in the original seed boxes, the casualties among them are, as a rule, exceedingly heavy before they reach the open ground, so that of the thousands leaving the nursery, a very small percentage survive. Results obtained in the past ten years clearly prove that the most satisfactory and the most profitable results can be obtained by growing our seedling trees to a good size in the nursery before they are sent out. This plays havoc with a nursery record of trees issued, but at the same time it renders the records of some value as an index to the number of trees which are actually planted out in the ground. The method of shipping trees to the other islands, which we have been forced to adopt, has proven not only efficacious but economical, for we so pack our trees that they can be shipped to any destination by parcel post at small expense. Should the rule forbidding the shipment of plants in soil be rescinded, we would still ship most of our trees in moss.

During the past ten years we have distributed from the Vineyard Street nursery over 1,250,000 plants.

Manoa Arboretum

It is obvious that we cannot correctly estimate the extent to which any tree can be employed in our forestry work until we have tested that tree out under the range of temperature, moisture and soil conditions afforded at various elevations

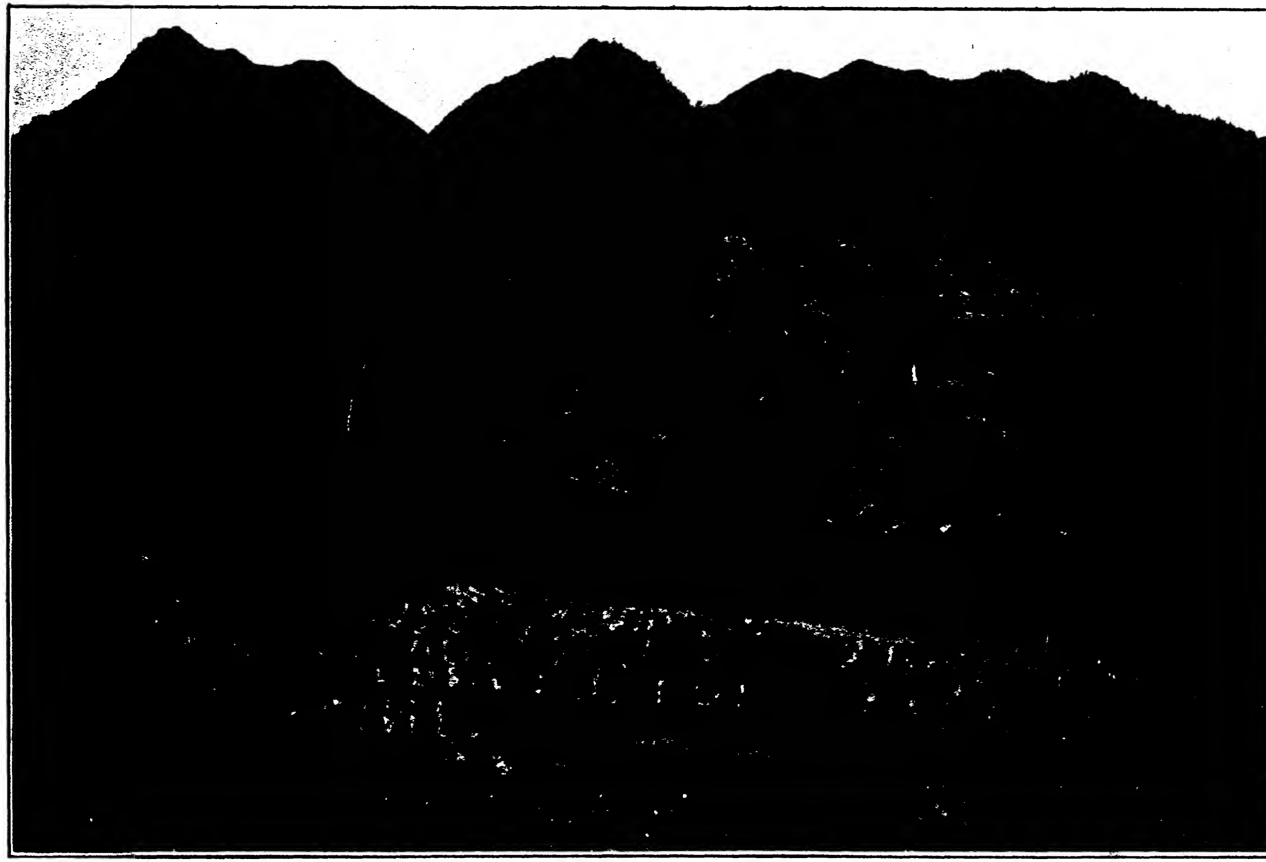


Fig. 8. Manoa Arboretum. A planted slope in the lower portion of Aihualama as seen from Haukulu. The trees are planted in rows cut through the heavy growth of Para grass. Stakes bearing the numbers of the rows may be seen along the trail which runs up the valley at the bottom of the planted ridge.

and in various parts of these islands. This would require that we undertake planting operations in several or many localities on each island of the group. The organization of our forest reserves was in such a state ten years ago, however, that it was quite evidently impracticable to at once lay out a large number of test gardens or arboreta in many localities. Seeds of foreign plants are usually obtained through correspondence with botanical gardens, botanists and collectors in other parts of the world. As a rule, seeds of desired plants are secured in small quantities only, and after these have passed through the vicissitudes of travel and one or more fumigations, they yield in most cases a very small stock of healthy seedlings. Many times we have obtained but one or two seedlings of some very desirable species of plant, the obtaining of the seeds of which had cost us much effort and time, and in some cases a considerable amount of money. In organizing and equipping the department of botany and forestry it was evident therefore that while a nursery was our first requisite, a second requisite of equal importance was a test garden or arboretum situated on a tract of land under the direct control of the Experiment Station, where we could test out all species of trees under consideration and where we could plant and care for the few specimens of rare plants reared from some of our seed introductions. Such a garden, to be most valuable, should be so situated that it would afford conditions of soil and climate approximating those obtaining on parts, at least, of the watersheds to be reforested. In addition to supplying trial grounds for our exotic plants, such a garden would in time be a source from which we could obtain seeds of those new plants which proved of promise, for the further distribution of the species on these islands.

Our plea for an arboretum received favorable consideration at once, and we began to cast about for a suitable piece of land for the purpose. When the Experiment Station acquired the Harrison property in the land of Haukulu, in upper Manoa Valley, during the early months of 1919, it was understood that not more than thirty acres would be devoted to sugar cane culture, while the rest of the area, some ninety-four acres, would be available to the department of botany and forestry for an arboretum. When we examined this property, however, it became evident that when the agriculturists had taken their thirty acres for cane culture, there would be left only pali land; sharp ridges with very steep slopes, which leaned up against sheer cliffs. These ridges were in reality talus slopes formed from debris which in times past had avalanched down from the cliffs above. A considerable part of the area allotted to us was already covered with native forests of complex composition, but with such trees as Koa, Kukui, and Lama predominating. While this land would afford us some room for tree planting, it was quite evidently inadequate for handling the problem confronting us, and so we began at once to seek an additional area. The land of Aihualama joined the newly acquired property of the H. S. P. A. throughout the length of Aihualama stream. Aihualama was owned in nearly equal parts by the B. P. Bishop Estate and Governor George R. Carter; the Bishop Estate land lying next to that of the H. S. P. A. A lease on the Bishop Estate land had recently expired and the trustees of that Estate desired to protect and develop this area as forest reserve as it was quite evidently an integral part of a watershed which was contributing to Honolulu's water

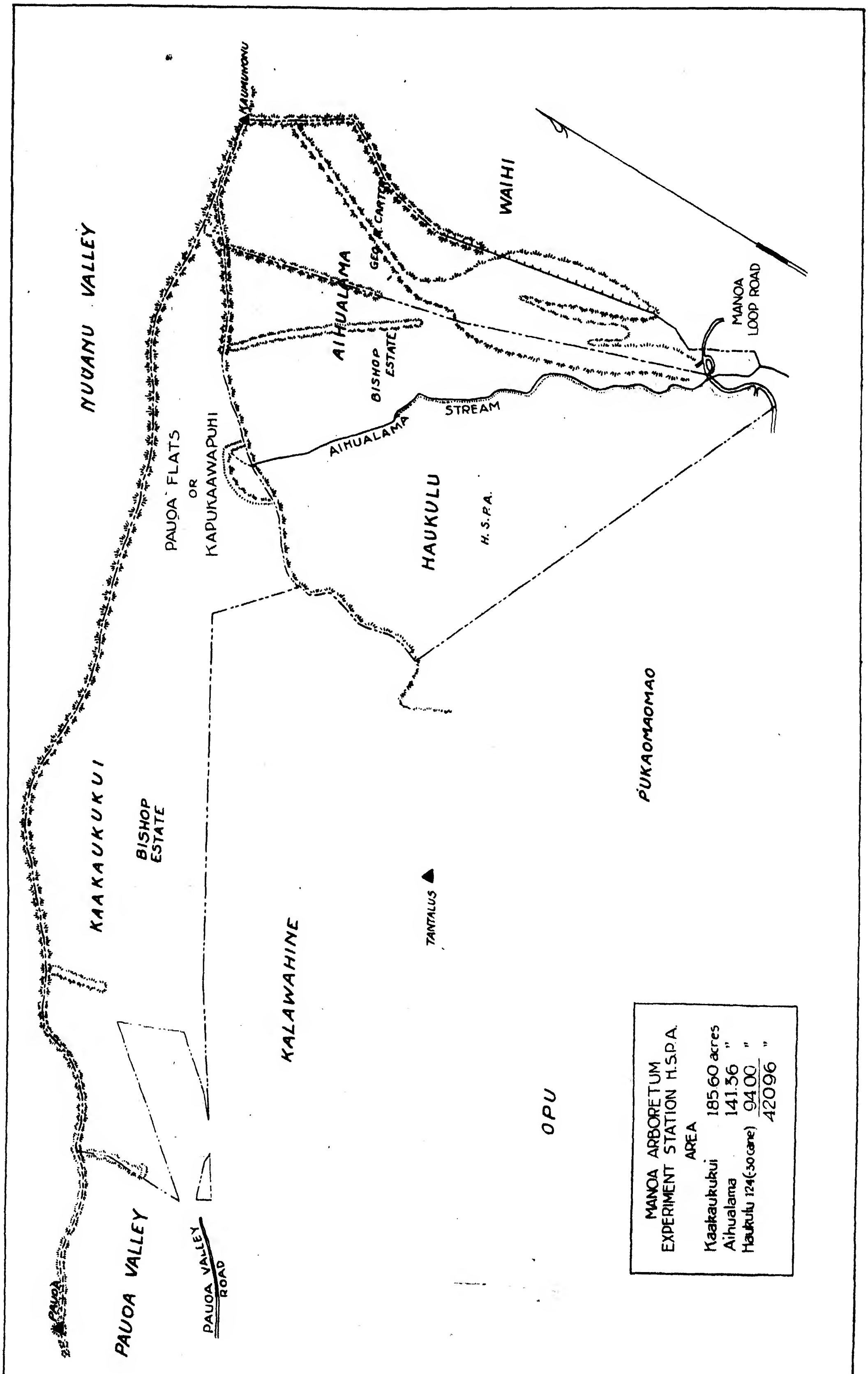
supply. It was obvious that in developing an arboretum on this land we would be improving it as part of the forested watershed, and negotiations with the trustees of the Bishop Estate soon secured for us a lease on this property for a thirty-year period from the first day of July, 1920, the H. S. P. A. contracting to pay rent of $1.00 on demand for the whole of said term. Covenants in this lease prescribing the uses to which we might and must put this property read as follows:

That he will use the demised premises only for the purpose of a forest reserve as part of the acclimatization garden and forest nursery of the Manoa Substation of the Experiment Station, Hawaiian Sugar Planters' Association, and maintain and utilize the same as an arboretum during the whole term;

That he will reforest that portion of the demised premises which is not adequately covered at the present time by forest (approximately 34.75 acres) with native and introduced trees and plants, properly spaced according to species, at the rate of not less than four (4) acres per annum.

Governor George R. Carter, the owner of the other half of Aihualama, became much interested in our undertaking to develop an arboretum on the Bishop Estate property adjoining his land, and in August, 1921, gave us a lease on his property to run for thirty years from the 23rd day of August, 1921. The terms of this lease were practically identical with those of the lease secured from the Bishop Estate, the stipulated rent being of exactly the same amount, to be paid under the same conditions. Governor Carter's property already carried a large grove of flourishing exotic trees which he had planted at considerable expense. The majority of the trees in this grove are Swamp Mahogany, *Eucalyptus robusta*, but it also contains several other species of Eucalyptus, the most notable of which is the Lemon Gum, *Eucalyptus citriodora*. Mahogany, Ironwoods, Tsugi, Wattles and Norfolk Island Pines are also present, and there are two fine fruiting specimens of the Turpentine tree, *Syncarpia laurifolia*. A single pine tree of undetermined species is making a successful struggle for existence. There are also several fine clumps of bamboo on the premises, in which at least three distinct species are represented. There is a very comfortable mountain house located in the upper end of the grove of exotic trees, and in the lease Mr. Carter has reserved the privilege of occupying this house for short periods each year. A famous swimming pool is located in one of the secluded valleys on the Carter property. This pool is kept constantly filled with clear, cold water which is piped down from a spring in the cliffs at the head of the valley.

By securing a lease on the two pieces of property in Aihualama we added an area of 141.36 acres to our arboretum. This gave us entire control over a secluded alcove in one corner of Manoa Valley. Roughly speaking it was a sextant of a circle, centered on the reverse curve in the government Loop Road, with its mauka boundary defined by the brow of the pali which roughly follows the arc of a circle. A very good idea of the configuration of this alcove may be obtained from the accompanying map and the photographs reproduced herewith as Figs. 5 to 8 inclusive. As in the case of Haukulu, the major portion of Aihualama is pali land, and a considerable part of this was occupied by native forest when we assumed possession. There was, however, some fifty acres suitable for use as trial garden.


NUUANU VALLEY
KAUMUMONU
WAIHI
GEO. R. CARTER
AIHUALAMA
BISHOP ESTATE
MANOA LOOP ROAD
AIHUALAMA STREAM
PAUOA FLATS OR KAPUKAAWAPUHI
HAUKULU
H. S. P. A.
PUKAOMAOMAO
KAAKAUKUKUI
BISHOP ESTATE
TANTALUS
KALAWAHINE
OPU
PAUOA VALLEY
PAUOA
PAUOA VALLEY ROAD
MANOA ARBORETUM
EXPERIMENT STATION H.S.P.A.
AREA
Kaakaukukui 185.60 acres
Aihualama 141.36 "
Haukulu 124(-30 cane) 94.00 "
420.96 "

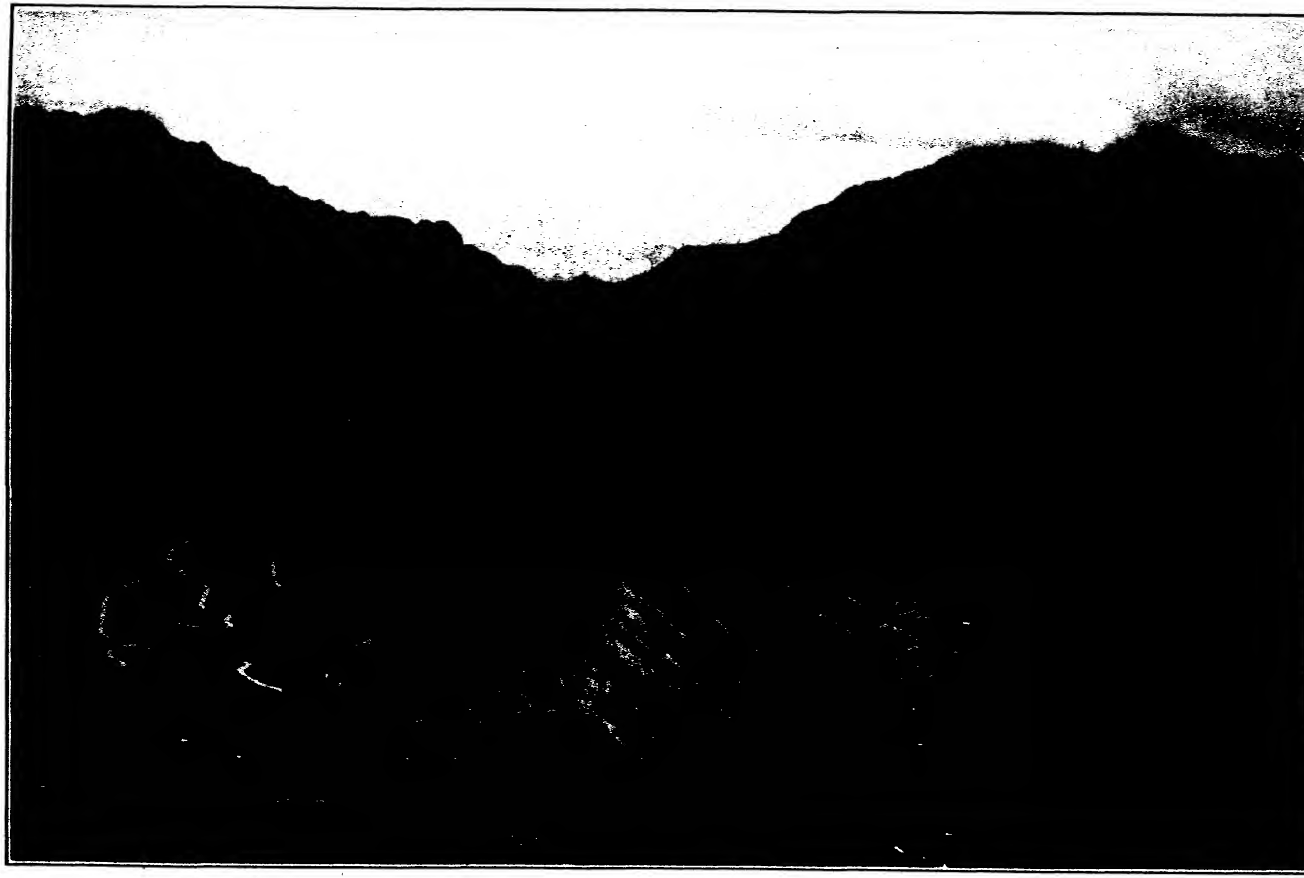


Fig. 9. Manoa Arboretum. The Kaakaukukui section as seen from the air at about two thousand feet elevation. Pauoa Valley occupies the foreground at the right and Nuuanu at the left, with Pacific Heights ridge extending up the center of the picture. This ridge in its upper portion constitutes the ewa boundary of the arboretum lands which extend across the hanging valley onto the slopes of Tantalus ridge. The highest cultivated lands seen in the upper end of Pauoa Valley extend beyond the makai boundary of the arboretum. Kaumuhonu, the mauka corner of the arboretum, is the peak directly in line with, and below, Konahuanui. This picture was taken by the Air Service of the U. S. Army, which has supplied us with a series of excellent photographs affording an unbroken panorama of both sides of the Koolau range.

This was in most part covered with Guava, Uluhi, Para Grass and Hilo Grass. Most of the land available for planting lay between the elevations of 400 and 1000 feet above sea level. There were a few small areas on pali slopes in which we might plant trees, thus carrying our operations on a small scale to an elevation of 1500 feet. While this property afforded us ample area for our immediate needs, it did not provide lands at high elevations, which seemed an essential requisite for proper experimentation along the lines which we should follow.

During our negotiations with the trustees of the B. P. Bishop Estate for the property in Aihualama, we learned that the Estate owned the land of Kaakaukukui, which joined Aihualama and Haukulu along the brink of the pali, and that the trustees were desirous of protecting and improving this land also as a part of Honolulu's forested watershed. As soon as we made known our needs for additional lands, they offered to lease to us all of their holdings in Kaakaukukui under terms identical to those in the lease of Aihualama, the lease to run concurrently with that of the last named property. A lease to Kaakaukukui was accordingly consummated, to run from the first day of January, 1924, for the term of twenty-six years and six months thence next ensuing.

The acquisition of Kaakaukukui added to our arboretum a total area of 185.6 acres. We estimated that in this land there was at least seventy acres from which the native forests had entirely disappeared, and this area was, of course, immediately available for arboretum purposes. Most of this denuded area lay between 1500 and 2000 feet elevation, and consequently afforded conditions of soil and climate absolutely essential for our purposes, but not to be found in Aihualama or Haukulu. Kaakaukukui takes in all of Pauoa Flats, and the better part of upper Pauoa Valley. Its ewa boundary runs along the crest of the ridge overlooking Nuuanu Valley. Its waikiki boundary starts from the highest point of Kaumuhonu and extends along the brink of the Manoa pali throughout the entire extent of Aihualama and half the mauka boundary of Haukulu. It then swings across the mauka slopes of Kalawahine and proceeds down the Pauoa slope of Tantalus ridge until it reaches the vegetable gardens of Pauoa Valley. The Pauoa Valley road extends to within a stone's throw of the makai boundary of this land. The shape and size of Kaakaukukui and its geographical relation to Haukulu and Aihualama may be seen by referring to our map. Kaakaukukui added many desirable features to the arboretum besides supplying us with the much needed land at high elevations for planting. Its strikingly irregular topography includes some most charming landscapes; brooks, streams, waterfalls, steep palis and sloping ridges arranged in picturesque combinations. It also carries extensive growths of native trees and plants in which are to be found numerous fine, healthy specimens of some rare and interesting species. We are striving to protect these remnants of a vanishing flora with judiciously placed barriers, and hope by so doing to preserve them as attractive features of our arboretum.

Pauoa Flats, or Kapukaawapuhi, affords a most interesting, and from our standpoint, most important physiographical feature. It is a hanging valley bounded on the Nuuanu side by a high, sharp ridge, and on the Manoa side by the opposed spurs of Kaumuhonu and Kalawahine, which are separated by a large

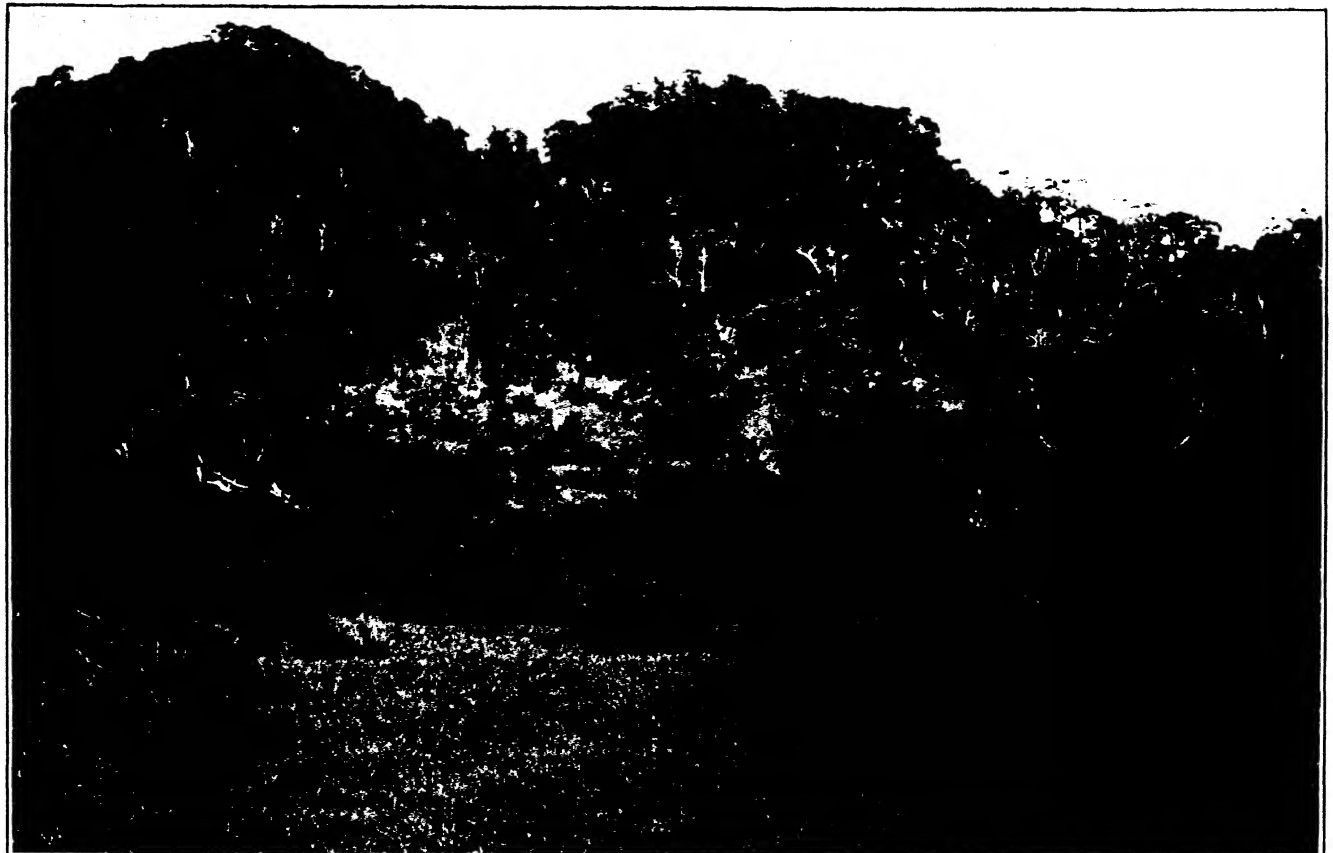


Fig. 10. Manoa Arboretum. Looking across Pauoa Flats towards the ridge above Nuuanu Valley. Kapukaawapuhi in the foreground is a bog covered with Hilo grass and bordered with guava bushes. Most of the native vegetation on the ridge in the background is dying or already dead.

and deep semicircular amphitheater cut into the crest of the Manoa pali. Kapukaawapuhi is the bottom of a diminutive water-catchment basin which drains via the amphitheater into Aihualama stream. Waters gathered in the amphitheater drop over the pali into Manoa Valley and, as Aihualama stream, flow through the lower section of the arboretum, constituting the boundary between Aihualama and Haukulu. This combination affords ideal conditions for the study of the influence of forest cover upon the run-off, and we shall observe with great interest any changes that take place in the Aihualama stream as a result of the reforestation of the catchment basin in which it takes its source. The topography of the Kapukaawapuhi basin and the condition of the vegetation which it carries is very well depicted by the photographs reproduced herewith as Figs. 9 to 12 inclusive.

In laying out and planting our arboretum to accomplish the purposes for which it was intended, it was necessary that all specimens planted be so located that their exact position could be recorded. The topography of the country in the arboretum was such that we could not lay it out in conventional geometrical figures bounded by roads and walks. The system adopted was the simplest and cheapest that we could devise. We first put in trails along the lines most easily traversed and then planted our trees in approximately parallel rows, at right angles to the general direction of a trail, each row continuing out from the trail until it reached some natural barrier, such as a gulch, the crest of a ridge, or existing forest. The main trails are divided up into numbered sections, the rows along each section are numbered and the trees are in turn numbered in the rows so that it is possible to keep a record of the exact position of each tree. In preparing the land for planting we have done no general clearing, but simply cut a wide swath through the guava bushes or uluhi fern along the line where a row of trees is to be planted. On the low and flatter lands we have, as a rule, spaced our rows approximately fifteen feet apart, and spaced the trees in the rows an equal distance apart. On steep slopes where the trees in one row will eventually overhang those in the row below, we have placed our rows much farther apart, the distance employed being determined by the slope of the land and the nature of the trees to be planted. We realized at the start that a spacing of fifteen feet apart each way would eventually bring our trees too close together if they all matured, but we also realized that many of the trees planted would undoubtedly fail to grow under the existing conditions, and that those which did survive and flourish would probably be provided ample space for their development through the death of some of their next door neighbors. In some cases we planted ten or more specimens of each species in a group with the intention of eliminating the poorer specimens when they began to interfere with each other. From the results obtained under our different methods of planting, we now aim to plant the different species in groups of ten to fifteen specimens whenever sufficient material is available to permit of this procedure. In mixed plantings it sometimes happens that several trees in close proximity to each other will flourish and that each one will prove to be the only surviving specimen of its kind in the arboretum. Under such conditions it is impossible to sacrifice any one of them when they begin to interfere with each

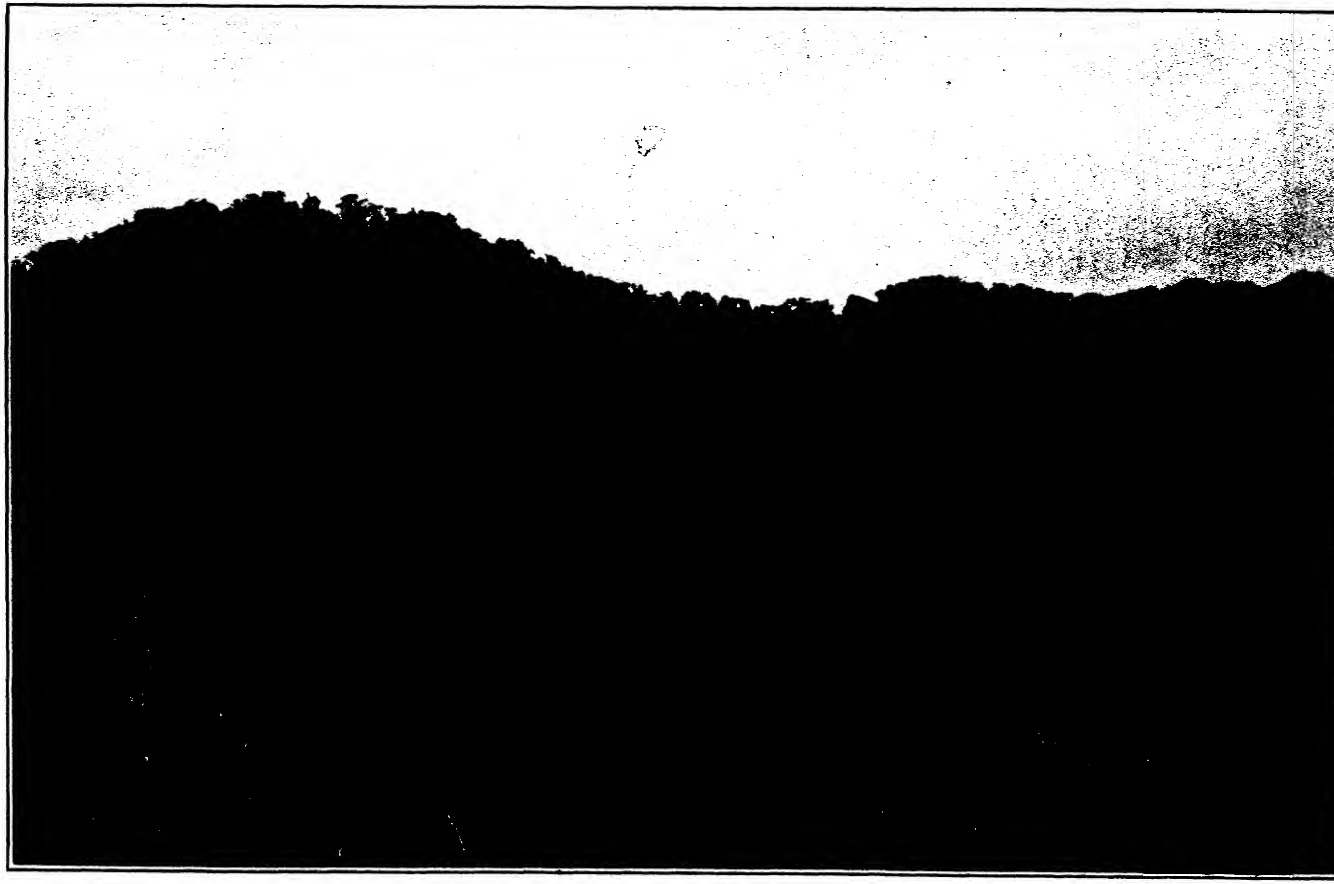


Fig. 11. Manoa Arboretum. Looking across Kapukaawapuhi from the rear slopes of Tantalus. The vegetation in the hanging valley is mostly guava bushes and Hilo grass, while some native vegetation still remains on the ridge above Nuuanu Valley.

other. We now strive to exercise great care in placing any single specimen of a rare tree that we secure.

At the present time most of the available land in Haukulu and Aihualama has been planted up. Shortly after securing Kapukaawapuhi we constructed a good trail on a moderate grade up the pali of Aihualama, emerging onto Kapukaawapuhi on the Konahuanui side of the amphitheater. Over this trail we have transported our material and made extensive plantings in a variety of habitats, including swamps, meadows, valleys, sloping hillsides and sharp ridges. Some of these plantings are in protected spots while others are fully exposed to the heavy winds which blow almost constantly across the flats from Nuuanu into Manoa Valley.

The building of effective water-conserving forests on our watersheds cannot be achieved by simply planting thereon groves of any tree that will thrive. This is fully demonstrated by the numerous planted groves of Eucalyptus to be found at various elevations on our mountain slopes. Obviously such groves do not fulfill the requirements, for what is needed are plant societies, including trees, shrubs, vines, herbs, ferns and mosses, which together form a water-conserving blanket of vegetation. Merely planting trees that will grow does not create such a plant society, or assure the segregation of appropriate plants into such a society. Just how the desired results can be accomplished through our efforts can be determined only through experiments. The Manoa arboretum is a field laboratory in which we are conducting such experiments. It not only affords us opportunities to test out plants of all descriptions under a variety of conditions, but also enables us to experiment with these plants in building plant societies.

From experiments in the Manoa arboretum we have already obtained results from which we can draw definite conclusions, and on which we can base definite recommendations. Up to the present time we have planted out in this arboretum one or more specimens of some nine hundred species of trees and shrubs. In the following list we name only those species, specimens of which have been in the ground four years or more, and have grown in such a way, and to such an extent, that we may safely conclude that they will continue to thrive and eventually reach maturity. The species showing the greatest promise are indicated by printing their names in bold-faced type. An asterisk in front of a name indicates that the plants of this species were reared from seed or cuttings of exotics already established in the Territory, while a dagger indicates that they were grown from seed obtained from abroad through the efforts of the department of botany and forestry.

† *Aberia gardneri*—Ceylon.
* *Acacia catechu*—East Indies.
† **Acacia confusa**—Philippines and Formosa.
† *Acacia robusta*—South Africa.
† **Acacia sp. No. 1338**—Fiji.
† **Acronychia laurifolia**—Tropical Asia.
* *Agathis robusta*—Australia.
† *Albizzia minahassae*—Celebes.
† **Albizzia moluccana**—Molucca Islands.
* *Albizzia procera*—Tropical Asia and Australia.
* **Albizzia stipulata**—East Indies.
* *Albizzia sp.*—Tropical Asia.

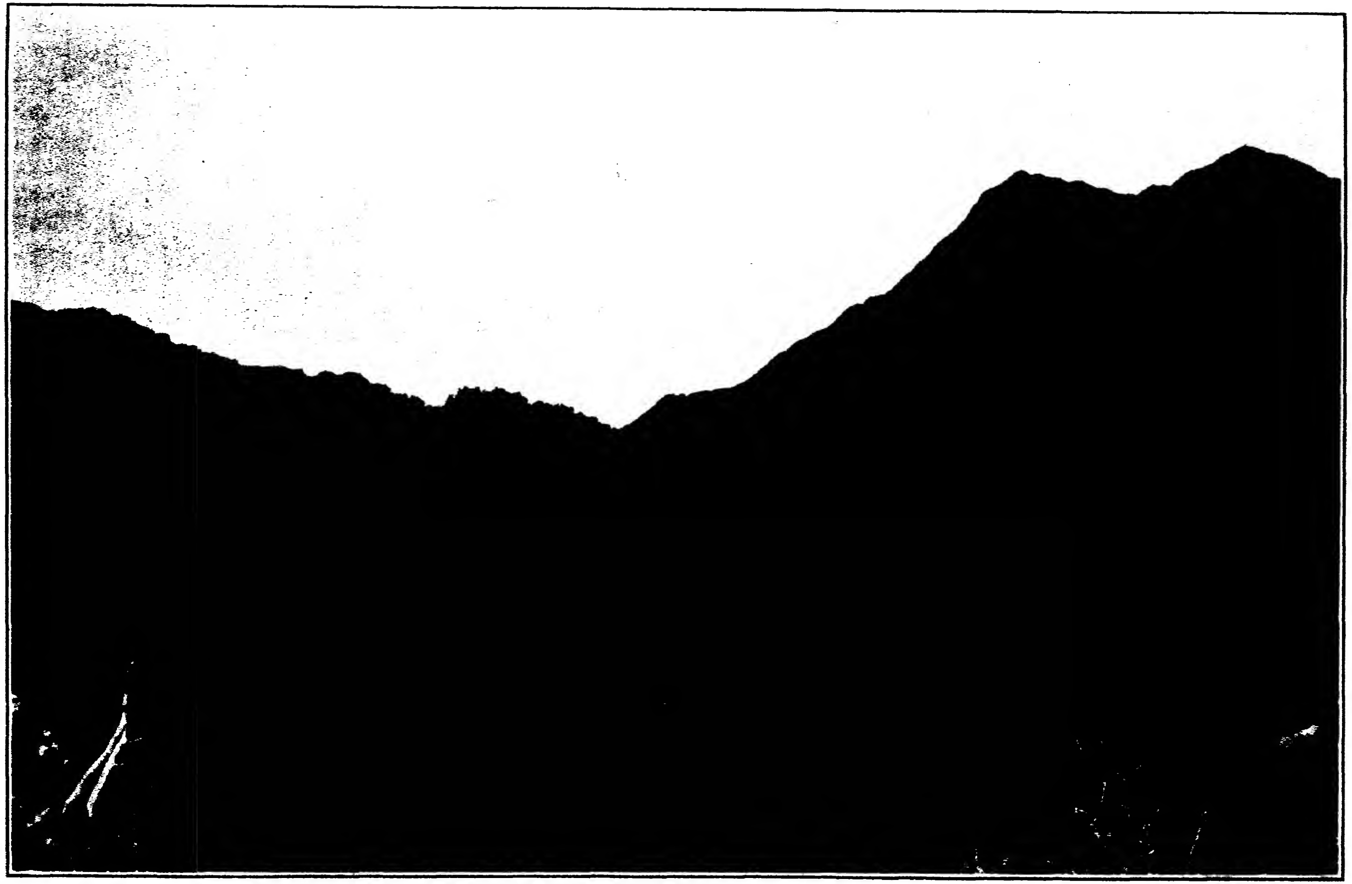


Fig. 12. Manoa Arboretum. Looking up Kaakaukukui towards the Nuuanu pali from the slopes behind Tantalus. The peak in the foreground on the right is Kaumuhonu, with Konahuanui directly behind it. The semicircular amphitheatre gouged in the crest of the Manoa pali occupies the center foreground of the picture. Aihualama stream takes its origin in this amphitheatre.

† **Alnus nepalensis**—Nepal.
† **Apeiba aspera**—Central America.
* **Araucaria bidwillii**—Australia.
* **Araucaria cunninghamii**—Australia.
* **Araucaria excelsa**—Norfolk Island.
* **Ardisia solanacea**—East Indies.
* *Artocarpus incisa*—Malaya and Pacific Islands.
† **Bambusa tulda**—Burma.
† *Barleria cristata*—Burma.
* *Barringtonia speciosa*—Polynesia.
* *Bauhinia variegata*—Southern Asia.
* *Bixa orellana*—South America.
* *Brassaia actinophylla*—Australia.
† *Brexia madagascariensis*—Madagascar.
† *Byrsonima crassifolia*—South America.
† *Caesalpinia melanocarpa*—Argentina.
† *Caesalpinia sp. No. 1299*—South America.
† *Callistemon citrina*—Australia.
† *Callistemon lanceolatus*—Australia.
* *Calophyllum inophyllum*—Polynesia.
* *Cananga odorata*—Malaya.
† *Canarium sp. No. 1474*—Malaya.
† *Cassia basilaris*—Tropical America.
† *Cassia moschata*—South America.
† **Cassia pilifera**—Brazil.
† **Cassia timorensis**—Timor.
† **Casuarina cunninghamiana**—Australia.
* *Casuarina quadrivalvis*—Australia.
† *Catalpa longissima*—West Indies.
† *Cecropia peltata*—Tropical America.
* **Cedrela australis**—Australia.
* **Ceiba pentandra**—West Indies.
† **Cerbera odollam**—Malaya.
† **Chamaecyparis lawsoniana**—United States.
† **Chrysobalanus icaco**—Tropical Africa.
* *Chrysophyllum cainito*—West Indies.
* *Cinnamomum camphora*—China and Japan.
* **Cinnamomum zeylanicum**—Malaya.
† *Cochlospermum hibiscoides*—Central America.
† *Cola acuminata*—Tropical Africa.
† *Combretum sp. No. 936*—Java.
† **Couthovia corynocarpa**—Fiji.
* **Cupressus pyramidalis**—Southern Europe.
* **Cupressus sempervirens**—Southern Europe.
† **Dillenia indica**—Tropical Asia.
† *Dillenia sp. No. 778*—Tropical Asia.
† *Diospyros mespiliformis*—Tropical Africa.
* **Dracaena marginata**—Madagascar.
* **Enterolobium cyclocarpum**—Brazil.
* **Eriobotrya japonica**—Japan and China.
* **Erythrina abyssinica**—North Africa.
* **Erythrina indica**—India.
† **Erythrina sp. No. 2300**—Central America.
† *Erythrophleum guineense*—Tropical Africa.
† *Eucalyptus alba*—Australia.

Fig. 13. Manoa Arboretum. A forest formation or plant society created in a valley in Haukulu by planting together numerous species of trees and shrubs. This planting was done in 1920 and the picture was taken in 1927. Photo by E. L. Caum.

* **Eucalyptus citriodora**—Australia.
* **Eucalyptus globulus**—Australia.
* **Eucalyptus robusta**—Australia.
* **Eucalyptus rostrata**—Australia.
† **Fagraea littoralis**—Java.
† *Fagraea obovata*—Malaya.
† **Ficus altissima**—India.
* **Ficus bengalensis**—India.
* **Ficus benjamina**—Malaya.
† **Ficus calophylloides**—Philippines.
† **Ficus ehretioides**—Australia.
† **Ficus eugenioides**—Australia.
† *Ficus forstenii*—Philippines.
† **Ficus glomerata**—India, Australia.
* **Ficus hispida**—Tropical Asia.
† *Ficus indica*—India.
* *Ficus infectoria*—Tropical Asia.
† *Ficus involucrata*—Java.
* **Ficus macrophylla**—Australia.
† **Ficus malunuensis**—Philippines.
† *Ficus nervosa*—Tropical Asia.
† **Ficus padifolia**—Mexico.
† **Ficus palawanensis**—Philippines.
† *Ficus polysyce*—Malaya.
† *Ficus pseudopalma*—Philippines.
* **Ficus retusa**—China, Malaya.
† *Ficus ribes*—India, Philippines, Java.
* *Ficus rumphii*—Malaya.
* *Ficus religiosa*—India.
† **Ficus stephanocarpa**—Australia.
† **Ficus sp. No. 876**—Malaya.
† **Ficus sp. No. 1272**—Siam.
† *Ficus sp. No. 1312*—Fiji.
† *Ficus sp. No. 1360*—Prince-of-Wales Island.
† *Ficus sp. No. 1466*—Philippines.
† *Ficus sp. No. 1486*—Siam.
† *Ficus sp. No. 1502*—Philippines.
† *Ficus sp. No. 1551*—Java.
* **Fraxinus sp. L246**— ?
† *Gonocaryum fusiforme*—Malaya.
† **Gourleia decorticans**—Chile.
† *Gynocardia odorata*—Burma.
† *Heliocarpus americanus*—Central America.
* *Heritiera littoralis*—Old world tropics.
† *Hernandia peltata*—Old world tropics.
† *Heterophragma adenophyllum*—East Indies.
* **Hibiscus elatus**—West Indies.
* *Hibiscus macrophyllus*—Malaya.
* *Hura crepitans*—South America.
† *Hydnocarpus anthelminticus*—Burma.
† **Ilex paraguayensis**—Paraguay.
* **Jacaranda ovalifolia**—Central America.
* *Jatropha curcas*—Tropics.
* **Juniperus australis**—Australia.
* **Juniperus bermudiana**—Bermuda.

Fig. 14. Manoa Arboretum. A very effective bit of rain forest on the Carter property created by planting ginger and a climbing aroid in a Kukui grove. This planting was done prior to our tenancy. A dense growth of ginger, with stems six to eight feet tall, covers the forest floor, while the trees hang full of the giant aroid. This combination is very pleasing to look upon, and at the same time constitutes a very efficient water-conserving plant society.

* *Kigelia africana*—South Africa.
† **Kydia calycina**—East Indies.
* *Lagerstroemia flos-reginae*—Tropical Asia.
† **Leptospermum gracilis**—Australia.
* *Lonchocarpus sericeus*—Tropical America.
* *Macadamia ternifolia*—Australia.
† **Macaranga grandifolia**—Philippines.
† **Macaranga tanarius**—Malaya.
† **Mallotus philippinensis**—Philippines.
* **Mammea americana**—Tropical America.
* **Melaleuca leucadendron**—Australia.
* *Melaleuca nesophila*—Australia.
* *Melochia indica*—India.
† *Melochia odorata*—Tanna.
† *Melochia sp. No. 1414*—Tropical Asia.
† *Mezzettia parviflora*—Borneo.
* **Michelia champaca**—Malaya.
* *Morus alba*—Asia.
† *Muntingia calabura*—West Indies.
† *Myroxylon sp. No. 2323*—Tropical America.
* *Nephelium litchi*—China.
† *Ochroma lagopus*—Tropical America.
* **Olea europaea**—Southern Europe.
† *Owenia cerasifera*—Australia.
† **Parkia africana**—Tropical Africa.
† **Parkia timoriana**—Timor.
* *Persea gratissima*—Tropical America.
* *Phyllanthus emblica*—Tropical Asia.
* *Pimenta officinalis*—West Indies.
† **Pithecolobium tortum**—Brazil.
† **Podocarpus cupressina**—Malaya.
† *Polyscias nodosa*—Malaya.
* *Pongamia mitis*—Nicobar.
* **Psidium cattleyanum lucidum**—Brazil.
* *Pterocarpus indicus*—Tropical Asia.
† *Pterocarpus marsupium*—East Indies.
† *Pterospermum sp. No. 1182*—Tropical Asia.
* **Ravenala madagascariensis**—Madagascar.
* **Rhus semialata sandwichensis**—Hawaii.
* *Rhus sp.*— ?
* **Sanchezia nobilis**—Ecuador.
* **Schizolobium excelsum**—Brazil.
† **Simaruba glauca**—Tropical America.
* *Spathodea campanulata*—South Africa.
* *Spondias lutea*—Tropics.
† *Sterculia alata*—East Indies.
† *Sterculia sp. No. 2267*—Tropical America.
* *Swietenia mahogani*—Tropical America.
* **Syncarpia laurifolia**—Australia.
* *Tectona grandis*—Tropical Asia.
† *Tecoma argentea*—Paraguay.
† *Terminalia arborea*—Java.
* **Terminalia arjuna**—East Indies.
† *Terminalia comintana*—East Indies.
† **Terminalia myriocarpa**—Burma.
† *Terminalia sp. No. 1696*—Tropical Asia.

† **Tetrazygia bicolor**—West Indies.
† **Thryalis braziliensis**—Brazil.
† **Trema orientalis**—Old world tropics.
* *Vitex pubescens*—Tropical Asia.
* *Vitex vestita*—Malaya.
† *Vitex sp. No. 1902*—Philippines.
† *Undetermined sp. No. 912*—Java.
† *Undetermined sp. No. 2243*—Central America.

Figs in Hawaiian Forestry

In our search among exotics for suitable trees to be used in the reforestation of Hawaiian watersheds, we early arrived at the conclusion that some species of the genus *Ficus* would not only be of great value in our forestry work, but might even prove a complete solution for some of our most serious problems. In a paper published in the *Planters' Record* for December, 1919, we presented our reasons for concentrating our attention on the genus *Ficus*, outlining the methods which we should follow, and indicating the results we might reasonably expect to obtain. In brief, we viewed the situation somewhat as follows: The genus *Ficus* includes over six hundred known species, and affords plant types ranging from tiny vines and shrubs to enormous trees attaining the greatest bulk to be found among existing plants. Trees of this genus occur throughout the tropics of the world, and constitute important elements in most rain forests, but the indigenous Hawaiian flora did not include a single species. Many figs show remarkable ability to grow and thrive under a great range of soil and climatic conditions. Figs are also noted for their ability to survive abuse and to recover after serious mechanical injury. Their great capacity for regenerating mutilated or amputated members may be taken advantage of by using slips or cuttings for propagating a species. As a matter of fact, this is the usual means by which ornamental figs are multiplied for commercial purposes.

In its native habitat, a fig tree produces enormous quantities of small seeds which are enclosed in fleshy pseudo-fruits or figs. These are usually sweet, thus making them an attractive food to such birds, bats and other animals as partake in part of a vegetable diet. A fig seed has a hard coat, and passes through the alimentary canal of an animal without having its vitality impaired. Living seeds are consequently deposited in all sorts of places by the birds and animals which have fed upon the fruits. Fig seedlings are by choice perching plants, and the majority of the fig trees in present day forests began their existence as seedlings perching on some other plant or the remains of some other plant, for they can start quite as well on an old stump or log as on the trunk or branch of a living tree. From such an elevated position a fig seedling throws its branches upward to form a crown, and sends its roots down to the ground to establish independent connections with the soil. These roots then thicken up and fuse together into a trunk which often surrounds and includes the object on which the seedling originally perched. Eventually a large tree develops, with a trunk capable of supporting the crown without the help of the host plant. In tropical forests it is often possible to determine that a big fig tree has developed from a seedling which perched on another tree at least a hundred feet above the forest floor.

Fig. 15. *Ficus altissima* in the Manoa Arboretum. The picture was taken when the tree had been in the ground five years and four months. This is one of the most promising of the many species of figs which we now have under trial. Photo by E. L. Caum.

Fig. 16. *Ficus altissima.* Trunk and aerial roots of the specimen pictured in Fig. 15 as they appeared when the tree was six years and four months old, showing by comparison the remarkable growth made in one year's time. Photo by E. L. Caum.

The unique role which the figs might play in Hawaiian forestry is very interesting to contemplate. There are on our watersheds extensive tracts still covered with dead and dying forests. This blanket of decrepit vegetation, with an invading undergrowth of Hilo grass and Uluhi, presents a serious obstacle to the planting of trees according to the usual methods followed in reforestation. This same vegetation, however, affords the precise conditions required for the natural spread of fig trees. If seed-bearing figs were prevalent in the vicinity of such a forest, and fruit-eating birds were present to eat the fruit and deposit the seed upon the dead and dying trees wherever they happened to perch, we might reasonably expect that fig trees would eventually become established throughout such a forest without any further help from the foresters. Perched upon a tree or log high above the forest floor, a fig seedling would in no way be disturbed by the Hilo grass and Uluhi, which would effectually smother all tree seedlings attempting to start up from the ground below.

To inaugurate a most desirable sequence of events it seemed only necessary therefore to infect our decadent forests at frequent intervals with seed-bearing fig trees. The mynah birds, which have an inherent taste for such food, would eat the figs and distribute the seed for us. We could not expect that the results obtained would be immediately noticeable, but we would have started a natural process of reforestation which would constantly gather headway as the number of fig trees multiplied. This proposition seemed so plausible and so certain of producing the desired results that we formulated a program which would serve to put it into active operation. When we took an inventory of the materials and forces which must be assembled we found that the project was already well advanced, but that we should have to supply a few very essential factors to make it effective.

An examination of our exotic flora showed that there were already present in Hawaii many mature specimens of figs, among which some twenty species were represented. The trees of several species were very evidently of a type that could be used to good advantage in our forestry work. Many of these fig trees were mature and flowered periodically or continuously; but every one of them failed to produce viable seeds. The reason for their delinquency in this respect was the absence of certain insects which carry the fig pollen from flower to flower and on which the plants rely for the execution of this important operation in their life cycle. In its native habitat, there is associated with each species of *Ficus*, a particular wasp which breeds within the figs, and in its endeavors to perpetuate its own species, conveys the pollen from the staminate flowers in one fig to the pistillate flowers in another, thus enabling the latter to set seed. Now, to render the local fig trees seed-producing, we should have to introduce their specific wasps. This seemed a simple matter, for we knew that our entomologists were accustomed to go even to the ends of the earth if need be, and bring back alive beneficial insects. We therefore selected from among the figs already present in Hawaii the species that seemed most suitable for forestry purposes, and then asked the entomologists to get the proper wasps for us. We realized that the task would require time, but we were confident that it would ultimately be accomplished.

Fig. 17. *Ficus bengalensis.* When this picture was taken the tree had been in the ground five years on an exposed Uluhi-covered ridge. This species can most certainly be used to goo l advantage in our forestry work. Photo by E. L. Caum.

Although there were several figs already represented by mature specimens here in Hawaii, these specimens were not located at strategic points on our watersheds. The first undertaking of our department in the active promotion of the fig project was to raise young plants and distribute them as widely as possible throughout the islands. Since the local trees did not produce seed, we had to import seed from abroad or rely on propagating the trees by means of slips or cuttings. In multiplying and distributing figs, we did not rely wholly on the species already present in Hawaii, but secured seed of as many species as possible, grew young plants of all of them and planted these out on our forest lands to determine which species grew best under our conditions, and produced trees most suitable for inclusion in our forests. It is perfectly safe for us to play with figs in this way, for none of them will spread naturally until we introduce their specific wasps, so if trees of any species show characters or habits which render them undesirable constituents of our forests, we simply neglect them, knowing that they will never spread. During the past ten years this department has secured seed of some eighty species of figs, grown young plants at the Vineyard Street nursery, and sent out seedlings for planting at many points for trial as to their suitability for forestry purposes. Those trees which survive in such situations may eventually become seed-producing and serve as a focus for the dissemination of their species if we introduce the necessary wasps to make them seed-bearing. In the Manoa arboretum there are now growing specimens of eighty-five species of *Ficus*. Most of these have been grown from seed, but a few were derived from cuttings from local trees and others from trees growing in foreign countries. The species which have proved most promising we have already indicated in the list printed on pages 76 to 83. For each of these species we should sooner or later secure the appropriate wasp to render our local specimens seed-producing. For species recently imported, this of course cannot be done until our local trees have reached fruiting size. A number of the species which we have been responsible for introducing into the islands are already represented by numerous fruiting specimens, and their wasps can now be imported, as they will find a constant supply of fruits in which to perpetuate their species.

When Mr. Pemberton went to Australia in 1920 his major project was to be the study of Australian figs and the wasps associated with them, with a view to introducing both into Hawaii and making them cooperative in our forestry work. He collected and forwarded to us large quantities of seed of numerous species of *Ficus* which he found growing in Queensland and New South Wales. From this seed we reared thousands of seedlings of each, and distributed them widely. Of two species, the Moreton Bay fig, *Ficus macrophylla*, and the Port Jackson fig, *Ficus rubiginosa*, we had found a few mature specimens here in Honolulu, and Mr. Pemberton soon undertook to send us the proper wasps for these. He gathered figs which were approaching maturity, and, placing them in containers of his own design, shipped them to Honolulu in cold storage. Shortly after these figs reached our laboratories, the wasps began to emerge and were liberated in the local fig trees, where they promptly established themselves. In a short time these trees began to produce quantities of figs containing viable seed, and from that time up

Fig. 18. *Ficus retusa* in the Manoa Arboretum. This, the well-known "Chinese banyan," seems to be one of the most promising trees for planting on our watersheds. This specimen had been in the ground five years and four months when the photograph was taken. Photo by E. L. Caum.

to the present, we have secured an abundant supply of local grown seed of these two species.

There is one large tree of *Ficus macrophylla* in Emma Square, and another in the old acclimatization garden on upper Nuuanu. These trees bear fruit the year round, but at certain seasons they drop an extra heavy crop during a period of three to four weeks. In 1922 we collected all the fruit we could get from one such crop dropped in a period of four weeks by the tree in the acclimatization garden. From this fruit we obtained 224 pounds of dry seed. We planted half an ounce of this seed, and from it secured 915 seedlings. At this rate our 224 pounds of seed, if all properly sown, would yield 6,558,720 seedlings. This one tree, in a single crop of fruit, produced enough seed, if it could be properly placed, to reforest all of the watersheds on these islands.

There is a single large tree of *Ficus rubiginosa* on the slopes of Tantalus above Makiki Heights. The wasps sent from Australia by Mr. Pemberton were liberated in this tree and established themselves there, causing the tree to produce viable seed. The fruits of *Ficus rubiginosa* are much smaller than those of *Ficus macrophylla* and the seeds are also smaller in about the same proportion. We have never made an attempt to estimate the seed produced in one crop by the specimen of the Port Jackson fig on Tantalus, but at times it must produce quite as many as does the Moreton Bay fig at the old acclimatization garden. A year or more after wasps had become established in the tree on Tantalus, Dr. Dean called our attention to a change which had taken place in the fruits produced by a fig tree on his premises in Manoa Valley. An examination of this tree showed that it was a Port Jackson fig, and that its fruits contained fully formed seed, as they were infested with wasps. These minute wasps had found their way to Dr. Dean's tree from the tree on Tantalus, over a mile away in a direct line. In migrating to this isolated tree in Manoa Valley they had to travel over the slopes of Round Top, making a considerable part of their journey against the trade winds. This seemed a remarkable feat for such tiny creatures, which appear to be very weak on the wing. However, in recent months we find that they have managed to travel unaided to such remote places as forests above Wahiawa and Laie, where there are now fruiting specimens of their host tree, developed from seedlings which we planted out six or eight years ago in these localities. The wasps of *Ficus macrophylla* are much larger than those of *Ficus rubiginosa* and appear to be stronger on the wing. They have also moved out unaided to other parts of the island, for just as fast as specimens of their host tree in our various plantings in the mountains reach fruiting size, the wasps appear on the scene to bring about the pollination of their flowers and render them seed-producing.

There is a third Australian fig, *Ficus glomerata,* in many of our forest plantings which is now producing an abundance of young fruits which never mature because the wasp of this fig has not yet been introduced. There were no specimens of this tree in the island when we undertook the fig project, all of our specimens having been grown from seed collected in Australia by Mr. Pemberton. When Mr. Pemberton left Honolulu a few months ago for Australia and New Guinea, he planned to ship this wasp from Queensland at the first opportunity

During his short stay in Queensland, however, he found no material in suitable condition for shipment, and consequently had to defer this operation until he returns to Australia from New Guinea. We are confident that he will succeed in introducing this wasp even as he did the other two.

There are a great many species of striking fig trees which range through India and the Malay Archipelago. Several of these, and particularly the Banyans and India rubber tree, are among the best known species of the genus *Ficus*, and are now widely distributed throughout the tropics of the world. These, and several other species of Oriental figs, were already represented in the exotic flora of Hawaii when we became interested in the genus, and some of these were included in our list of species for which wasps were desired. Hawaiian entomologists were making frequent visits and protracted stays in the Orient, and they gave this endeavor much careful attention. Dr. Williams, working in the Philippines, made several attempts to ship back insects to us, but the time consumed in the journey proved too long, the insects all emerging from the fruits and dying before their arrival in Honolulu. Mr. Fullaway shipped some figs containing insects from Hongkong. Most of the insects emerged and died during the journey, while the few which emerged after the fruits reached our laboratory were apparently too weak to function, for although we gave them every care and attention, they failed to establish their species in our trees. Of all the fig trees which we have tested out to date, the Chinese Banyan appears to be one of the very best for our purposes. Fruiting specimens of this Banyan are numerous in Hongkong and from this source we have tried to secure the proper wasp. All of our attempts up to the present time have failed, but we are now devising schemes whereby we believe we shall be able to bring these insects through alive. Their successful introduction is a matter of such importance to Hawaiian forestry that we believe we are justified in sending a specially equipped expedition to Hongkong to accomplish this errand.

During the past ten years we have had added to our exotic flora a great many species of Oriental figs. Through the painstaking efforts of Dr. Williams we received quantities of seed of many of the more important species of *Ficus* which ranged through the Philippine Islands. Specimens of some of these species have now reached fruiting size in our cultures, and will become seed-producing whenever we bring in their respective wasps.

If fig seeds will germinate and develop into trees when sown in elevated positions by birds, they should do the same if sown in similar positions by the hand of man. We therefore started experiments of throwing seed into such positions when traveling through the forests on foot. When retracing our footsteps in later months, we found thriving fig seedlings in positions where we had previously thrown seed. If this operation resulted in success, why would it not be possible to fly over our decadent forests in an airplane, dropping fig seed wherever favorable conditions seemed to exist for their reception. It is obvious of course that most of the seed so dropped would land in situations where it could not grow and thrive, but if one tree eventually matured for every hundred thousand seeds so sown, the results obtained would be worth the effort. From the statistical informa-

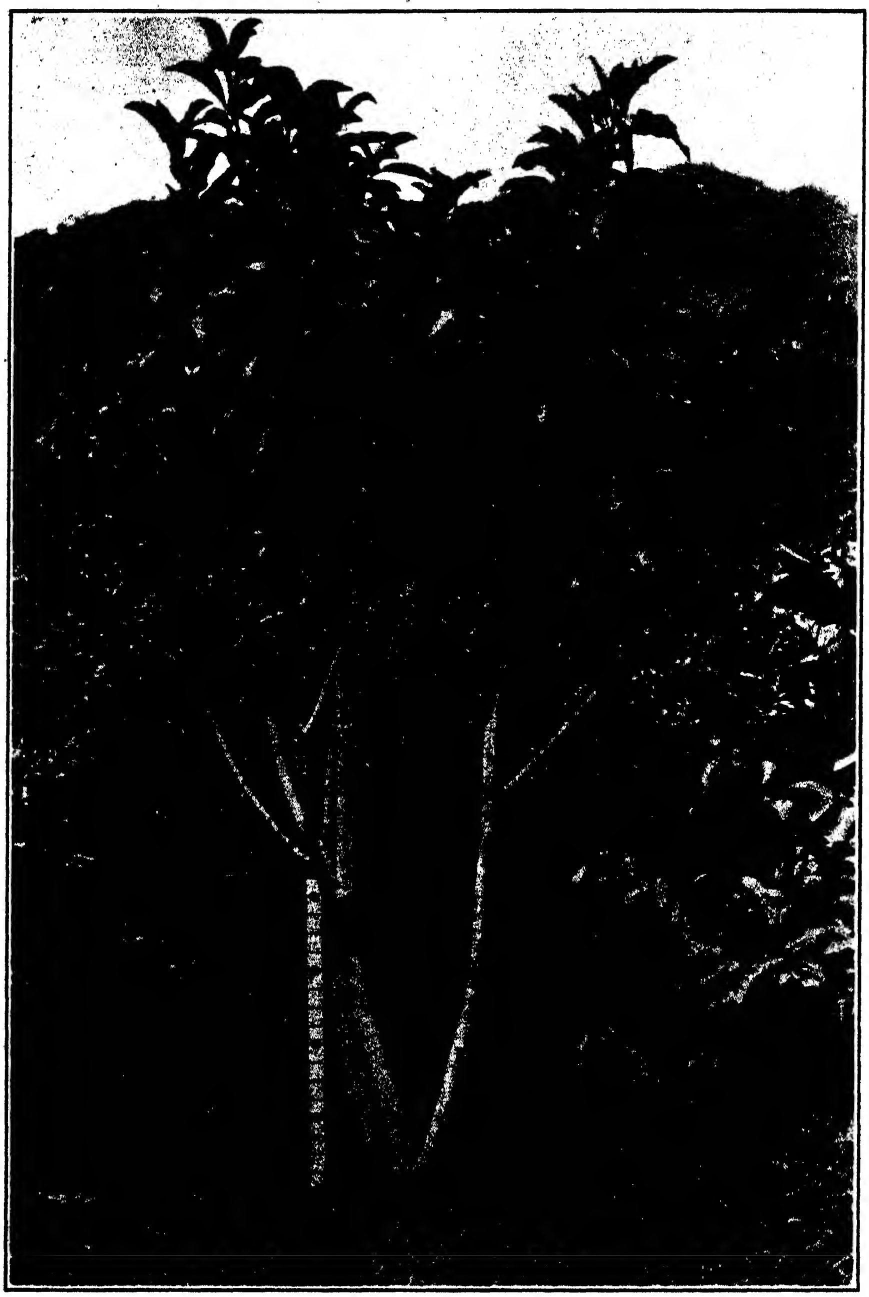


Fig. 19. *Ficus hispida* in Manoa Arboretum. Trees of this species do not attain great size, but they are extremely hardy, fruit heavily, and are said to spread rapidly in their native habitat. This specimen had been in the ground five years when the above picture was taken.

Fig. 20. *Ficus hispida* in Manoa Arboretum. Trunk of the specimen shown in Fig. 19 as it appeared two years later. Numerous leafless branches springing from the trunk bear figs in great numbers. Photo by E. L. Caum.

tion given above, it is evident that enormous numbers of fig seeds can be obtained at little expense. By using an airplane, a reasonable number of these seeds could be deposited where they would germinate and produce trees in situations practically impossible of approach in any other manner. The Air Service of the U. S. Army has shown great willingness to assist us in this endeavor, and already many sowings of seed have been made from Army airplanes on the forest reserves of Oahu. On one occasion, while on a visit to the island of Hawaii, several planes distributed seed over the Panaewa Forest Reserve which had been laid waste over a considerable area by a forest fire.

When in 1919 we wrote the paper previously alluded to, recommending the use of figs in our forestry work, we confidently stated that they would prove of great value to us. The experimental work which we have done with figs since that time has demonstrated that our confidence was in no way misplaced, for if we erred, it was in underestimating their value. We now have in our cultures a dozen or more species that grow luxuriantly on our watersheds and produce trees of an ideal type for inclusion in a rain forest. Some of these figs are superior in every way to any and all other trees in our cultures. We have demonstrated beyond a doubt that we can successfully build forests with fig trees as their major constituents.

We have learned many interesting and helpful facts regarding the culture and propagation of figs. Young seedlings of many species are rather difficult to handle in the nursery because they do not like to start out in life from the position in the soil where we are wont to plant the seeds. They prefer to spend their youth in some elevated and well aerated situation. After the seedlings have reached a height of two or three inches they can be readily handled according to ordinary nursery practice. Most of the figs can be propagated in the field by simply thrusting cuttings into the soil. Some species give much better results than others when handled in this manner. We have found that, as a rule, we could get more strikes from cuttings placed in the soil in the Manoa arboretum than we could obtain from similar cuttings placed in soil or sand in boxes at the Vineyard Street nursery. Good results have been secured from moderate sized cuttings which were simply thrust into the soil in Hilo-grass-covered areas. The resulting trees were able to come through without any cultivation, as they formed crowns well above the Hilo grass. Our laborers in the arboretum, upon discovering that cuttings of certain figs rooted freely, started a planting campaign of their own. As a result, we now have some fig trees in situations which were being reserved for other plants.

Our fig project has successfully passed the critical tests and we can proceed with its further elaboration with every assurance that we are laying the foundations for a natural and permanent rejuvenation of our forests. Specimens of many good species of fig are already widely distributed on our watersheds, but we should now undertake systematically to build orchards of the better species at frequent intervals in the borders of all our rain forests. Whenever a sufficient number of specimens of any good species reach maturity in our cultures, we should take the necessary steps to introduce the wasp belonging to that species,

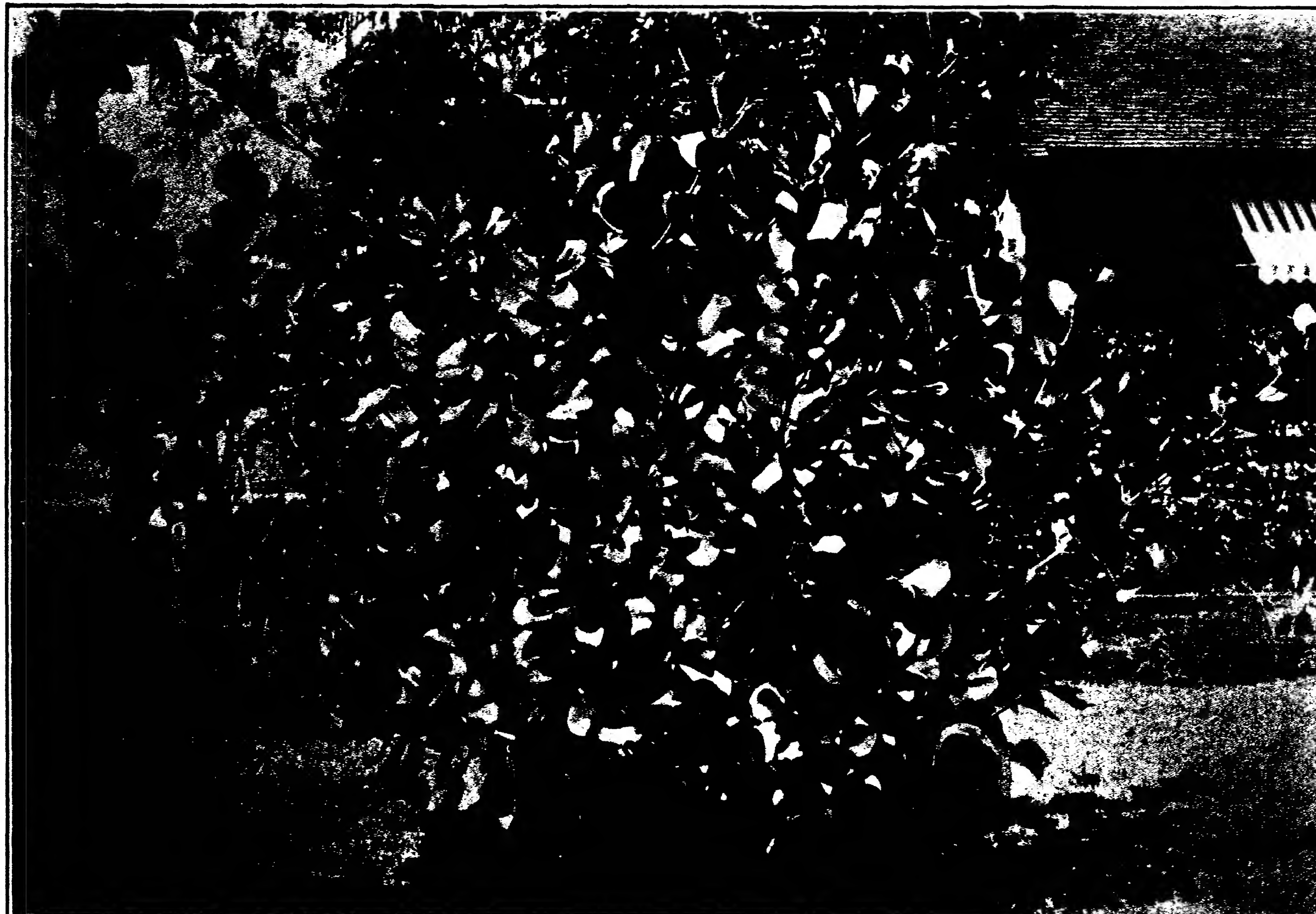


Fig. 21. *Clusia rosea.* A "Scotch attorney" residing in Honolulu in the neighborhood of the Experiment Station. Photo by E. L. Caum.

and thus render our local trees seed-bearing. Several remarkable species of figs are already represented by such a number of mature specimens as would serve to maintain their wasps should these be introduced at this time. It is obvious therefore that the next step in the development of our fig project should be the introduction of fig wasps from abroad.

Another phase of the fig project which might well receive special attention is the introduction of additional fruit-eating birds to aid the mynah in the distribution of fig seeds in our forests. When returning from Panama last winter we were able to secure and bring back to Hawaii a few pair of three species of Central American game birds for release in our forests. In introducing these birds we were acting on written and cabled instructions from officers of the Board of Commissioners of Agriculture and Forestry. All of these birds are fruit-eaters and tree-dwellers, and if they become established in our forests, will prove far more efficacious than the mynah in distributing fig seed in the localities where we are particularly desirous of getting them placed. It would be a good policy to bring in more of these same birds as soon as possible so as to insure the establishment of their species in our forests.

Introducing the Scotch Attorney

During our stay in Cuba in 1920 we made the acquaintance of another tree with habits somewhat like those of the figs. We did not learn the Cuban name for it, but its scientific name is *Clusia rosea.* It has fan-shaped leaves four to eight inches broad which are rather fleshy and quite rigid. It produces large, handsome, rose-colored flowers, and attractive fruits two to three inches in diameter. Like those of the figs, the seedlings of *Clusia* prefer to start out in life in some elevated position. They may perch on a tree, but they seem equally satisfied to start on a stone wall or a bare rocky cliff. I found several seedlings one to two feet tall growing on a stone wall. They had numerous roots intertwined over the surface of the wall, but so far as I could find, none of these roots had as yet established connections with the soil. While in Cuba I collected a quantity of seed of this tree, but it failed to yield any seedlings when planted upon my return to Honolulu. After repeated attempts I finally succeeded in raising two seedlings from a small quantity of seed forwarded to me by Mr. Gray, of the Harvard Botanical Garden at Soledad, Cuba. These seedlings have now developed into sizeable trees but neither has as yet flowered. We have, however, succeeded in rooting numerous cuttings, by which means we have increased the population and distribution of this tree in Hawaii.

During our recent visit to Trinidad and British Guiana we met with the same and other species of *Clusia,* all displaying similar habits and characters to those mentioned above for *Clusia rosea.* In Trinidad they call a tree of this nature a "Scotch attorney." It merits this name, I was told, because "it always squeezes its client to death." In Trinidad, Clusias range from sea level to the tops of the mountains which reach 3000 feet in elevation. One species, *Clusia intertexta,* is the most conspicuous and abundant component of the flora on the summit of their

highest mountain, the Aripo, where it forms almost impenetrable jungle with its long straggling branches and intertwining aerial roots.

The Clusias are spread even as the figs are spread. They offer some advantages, however, over and above those presented by the figs, for in addition to starting on trees, logs, etc., they show a special inclination to start on open rocky land and exposed barren palis where they produce dense vegetation, which clings to the substratum with great tenacity. Then, the Clusias do not require the assistance of specific insects to bring about the pollination of their flowers.

The Filtration of Settlings

By H. F. Bomonti

In a previous report on the treatment of settlings and the Oliver Filter, published in the *Record*, Volume XXXI, No. 1, detailed data, showing the effect of various treatments on the filtration characteristics of settlings are given. The data in the above mentioned report were all taken from the tests made at the Oahu Sugar Company. For this reason the writer visited a number of factories, located on all the islands and in the various districts on each island, to determine the filtration characteristics of the settlings when subjected to the same chemical treatments.

Tests were made at eighteen factories, not including Oahu Sugar Co. They are as follows:

Oahu. Honolulu Plantation Co., Ewa Plantation Co., Waialua Agricultural Co., Kahuku Plantation Co.

Maui. Pioneer Mill Co., Wailuku Sugar Co., and Maui Agricultural Co.

Hawaii. Hawaiian Agricultural Co., Olaa Sugar Co., Waiakea Mill Co., Hilo Sugar Co., Laupahoehoe Sugar Co., Honokaa Sugar Co., Hawi Mill & Plantation Co.

Kauai. Makee Sugar Co., Lihue Plantation Co., Hawaiian Sugar Co., Kekaha Sugar Co.

The experimental filter unit and also the method of procedure in making these tests are fully described in the article already referred to. Filtration tests were made on the settlings as discharged from the settling tanks without preliminary treatment, after liming to 8.5 to 8.9 pH, and after acidifying the limed settlings with phosphoric acid to 6.8 pH. This latter treatment is known as the Borden process.

In view of the successful operation of the Oliver Filter at the Oahu Sugar Co., complete data were secured on the Borden treated settlings in order to determine the range of variability of the settlings that might be encountered in applying the filter to the industry generally. Samples were examined at the above factories in an effort to cover variations that might come from cane variety, climate, soil, flum-

ing, and factory equipment. At none of these plantations were enough samples taken to make the work representative of the condition of the settlings as it might vary throughout the season.

The composition of the suspended solids in settlings varies considerably during the year, and, perhaps, more so on the non-fluming plantations than on the fluming plantations. For this reason, all comments on the filtration characteristics of the settlings at any of the factories refer solely to the conditions which prevailed at the time of these visits.

The filtration data of the settlings for each factory have been tabulated and discussed in the following pages. The term "filtration rate" has been used in the text instead of the phrase "volume of filtrate" as given in the tables.

Filtration data of the settlings of Honolulu Plantation Company. Date of tests, April 18, 19, 20, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
350 cc.	..	...	6.8	1025 cc.	235 gms.	1/4 "	35 secs.	3.5
500 "	..	...	6.8	1000 "	...	1/4 "	..	..
...	8.6	875 cc.	6.7	1050 "	240 "	1/4 "	40 "	3.5
775 "	8.6	1025 "	6.9	1275 "	125 "	3/32"	25 "	1.8
475 "	..	...	7.0	975 "	300 "	5/16"	40 "	4.7
600 "	8.7	1000 "	6.8	1325 "	115 "	3/32"	25 "	1.6
400 "	..	...	6.8	1600 "	280 "	5/16"	35 "	3.0
300 "	8.6	600 "	6.8	800 "	300 "	5/16"	30 "	5.5
400 "	..	...	6.9	1450 "	365 "	3/8 "	25 "	4.0
Av. 475 cc.	8.6	875 cc.	6.8	1167 cc.	245 gms.	1/4 "	32 secs.	3.45

The filtration characteristics of the settlings at this factory are very similar to those found at the Oahu Sugar Company in their response to lime and phosphoric acid (Borden process). The relatively low initial filtration rate for untreated settlings is quite characteristic of the settlings at Waipahu. After liming to 8.6 pH there is an increase in filtration rate amounting to over 100 per cent. Further acidifying these limed settlings to 6.8 pH results in an increase of the filtration rate.

The cake formed during these tests averaged ¼", cracking in slightly over 30 seconds. This indicates that the cake was quite porous and should be easily sweetened off. Studying the data, it will be observed that there is quite a wide variation in the suspended solids in the settlings. These differences were due largely to the type of settling tanks in use at the time. With a Dorr clarifier (to be in use for the 1929 crop) it is quite likely that the per cent suspended solids in the settlings will be more uniform.

Filtration data of the settlings at Ewa Plantation Company. Date of tests, February 15, 16, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
...	8.4	800 cc.	6.8	1400 cc.	124 gms.	3/32″	60 secs.	1.6
...	8.7	800 "	7.1	1150 "	110 "	3/32″	45 "	1.7
...	9.0+	825 "	6.8	1150 "	140 "	1/8 ″	45 "	2.0
...	9.0+	950 "	6.8	1140 "	130 "	1/8 ″	45 "	2.0
900 cc.	8.8	1025 "	6.9	1350 "	145 "	1/8 ″	48 "	1.9
900 "	8.6	950 "	6.8	1375 "	140 "	1/8 ″	45 "	1.8
Av. 900 cc.	8.8	900 cc.	6.9	1260 cc.	131 gms.	1/8 ″	48 secs.	1.8

The per cent suspended solids of the settlings at this factory is very low, varying from 1.6 to 2.0 per cent. Although the tests showed a fair response to the phosphoric acid treatment, resulting in a filtration rate of 1260 cc., the cake which was formed was less than ⅛″ in thickness. The time of cracking was 48 seconds. This is high for such a thin cake, indicating that the cake is not very porous. The mill juices at Ewa are strained through a No. 00 screen having 625 perforations per square inch. This fine screen removes a large portion of the fiber or cush cush, which would be present in the juice provided coarser screens were used. The writer believes that it is a good practice to use fine mill screens, provided good results can be secured with the presses.

Filtration data of the settlings at Waialua Agricultural Company. Date of tests, April 21, 22, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
700 cc.	8.6	800 cc.	6.8	1075 cc.	180 gms.	3/16″	50 secs.	2.9
750 "	..	...	6.8	2050 "	240 "	1/4 ″	55 "	2.1
700 "	8.5	850 "	6.9	1250 "	150 "	1/8 ″	45 "	2.0
...	9.0+	825 "	6.8	1250 "	245 "	1/4 ″	30 "	3.3
700 "	8.7	800 "	6.8	1000 "	83 "	3/32″	40 "	1.5
...	9.0+	950 "	6.8	1200 "	200 "	3/16″	50 "	2.9
Av. 710 cc.	8.8	845 cc.	6.8	1300 cc.	183 gms.	3/16″	45 secs.	2.45

One of the characteristics of the settlings at this factory is the higher filtration rate of the settlings as discharged from the settlers. The effect of liming and the phosphoric acid treatment results in filtration rates approximately the same as found at Waipahu. The cake formed during these tests was 3/16″ in thickness and cracked in 45 seconds. This fairly high cracking time indicates that the cake is not very porous. The suspended solids in the settlings vary considerably, from 1.5 to 3.3 per cent.

Filtration data of the settlings at Kahuku Plantation Company. Date of tests, April 25, 26, 27, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
700 cc.	8.8	850 cc.	6.8	1000 cc.	175 gms.	5/32"	35 secs.	2.9
750 "	8.6	1150 "	6.8	1300 "	270 "	7/32"	30 "	3.3
775 "	8.6	850 "	6.8	1050 "	185 "	3/16"	40 "	3.0
800 "	8.7	950 "	6.8	1200 "	230 "	1/4 "	35 "	3.2
750 "	..	...	6.8	1225 "	215 "	3/16"	40 "	3.0
725 "	9.0+	850 "	6.9	1075 "	150 "	1/8 "	..	2.5
575 "	8.6	775 "	6.7	975 "	135 "	1/8 "	35 "	2.4
800 "	8.5	875 "	..	1200 "	200 "	3/16"	40 "	2.8
Av. 730 cc.	8.7	900 cc.	6.8	1130 cc.	195 gms.	5/32"	36 secs.	2.9

The filtration rate of the untreated settlings at this factory is considerably higher than that usually found at Waipahu. However, after liming and acidifying with phosphoric acid, the filtration rate is less than the average. The cake was only 5/32" in thickness, cracking in 36 seconds. This rather low cracking time indicates a fairly porous cake. The suspended solids in the settlings are quite uniform, varying from 2.4 to 3.3 per cent, and averaging 2.9 per cent.

Filtration data of the settlings at Maui Agricultural Company. Date of tests, May 3, 4, 5, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
800 cc.	8.6	800 cc.	6.8	950 cc.	140 gms.	1/8 "	60 secs.	2.5
675 "	8.7	675 "	6.9	925 "	132 "	3/32"	65 "	2.5
875 "	8.5	925 "	6.9	1050 "	93 "	1/16"	55 "	1.6
575 "	8.8	600 "	6.8	750 "	240 "	3/16"	50 "	4.8
1050 "	8.6	1125 "	6.8	1250 "	92 "	1/16"	50 "	1.4
Av. 795 cc.	8.7	825 cc.	6.85	985 cc.	140 gms.	3/32"	56 secs.	2.56

Although the settlings at this factory are returned to the mill, it seemed desirable to secure some data at this factory because of the particular conditions which exist there. The juices are strained through a Peck strainer, covered with a 125-mesh screen. The limed juices are settled in Dorr clarifiers, using both primary and secondary units. The settlings from the Dorr were then resettled. In spite of this long settling cycle, a large volume of settlings was secured. The average filtration rate of the untreated settlings was higher than any tested at that time. It is interesting to note that the response to lime is very slight, while the response to the phosphoric acid treatment is slightly greater. As was to be expected, a thin cake was formed, averaging 3/32", and cracking in 56 seconds. This cracking time is

quite high and is characteristic of this type of settlings. From all experience with fine strained juices, the settlings can not be satisfactorily handled in the filter press. Perhaps were it possible to construct a filter with very thin frames, the settlings could then be filtered.

Filtration data of the settlings at Pioneer Mill Co. Date of tests, May 6, 7, 9, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
360 cc.	8.8	475 cc.	6.8	1350 cc.	420 gms.	7/16″	30 secs.	4.7
350 "	9.0	750 "	6.9	1600 "	260 "	1/4 ″	25 "	2.8
650 "	9.0	950 "	6.8	1375 "	175 "	3/16″	30 "	2.3
375 "	8.5	850 "	6.8	2350 "	550 "	5/8 ″	30 "	3.3
725 "	9.0	1400 "	6.8	1900 "	700 "	3/4 ″	25 "	5.0
Av. 492 cc.	8.9	885 cc.	6.8	1715 cc.	420 gms.	7/16″	28 secs.	3.6

The filtration characteristics of the settlings at this factory were improved to a very great extent by the Borden process. The filtration rate of the untreated settlings was very low in some tests, the average being about the same as that found at Oahu. On liming these settlings the filtration rate increased approximately 80 per cent. When these settlings were then acidified to 6.8 pH with phosphoric acid, the rate was increased almost 100 per cent above that of the limed settlings. These high filtration rates compare well with the best that were found at Oahu Sugar Co.

An average cake of 7/16″ in thickness was formed, and although the cake was about five times as thick as that formed at Maui Agricultural Co., it cracked in half the time. The influence of the cush cush on the porosity of the cake is well brought out in this example.

Filtration data of the settlings at Wailuku Sugar Co. Date of tests, May 10, 11, 12, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
700 cc.	8.8	700 cc.	6.8	900 cc.	125 gms.	1/8 ″	50 secs.	2.4
700 "	9.0	825 "	6.8	975 "	133 "	1/8 ″	55 "	2.4
1175 "	8.6	1275 "	6.9	1550 "	154 "	3/16″	50 "	1.8
600 "	8.8	725 "	6.9	825 "	100 "	3/32″	50 "	2.2
600 "	8.8	675 "	6.8	675 "	80 "	3/32″	50 "	2.0
500 "	8.8	600 "	6.8	675 "	80 "	3/32″	50 "	2.0
725 "	8.9	800 "	6.7	875 "	90 "	3/32″	55 "	1.8
Av. 700 cc.	8.8	800 cc.	6.8	925 cc.	109 gms.	7/64″	51 secs.	2.1

Although the untreated settlings at this factory had a filtration rate which was somewhat better than that found at the Oahu Sugar Co., after liming these settlings there was only a slight improvement in the filtration rate. After adding phosphoric acid, the filtration rate increased slightly but was considerably lower than the average found at Oahu Sugar Co. A thin cake was formed, averaging only 7/64" in thickness, and cracking in 51 seconds. Considerable difficulty was experienced in filtering these settlings in the presses. This will be more fully discussed in another part of this report.

Filtration data of the settlings at the Lihue Plantation Co. Date of tests, May 16, 17, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
400 cc.	8.5-8.8	500 cc.	6.8	800 cc.	...	1/4 "	47 secs.	..
450 "	"	700 "	6.8	1050 "	115 gms.	1/8 "	50 "	2.0
...	"	700 "	6.8	890 "	...	1/16"	..	..
700 "	"	950 "	6.8	1050 "	125 "	1/8 "	45 "	2.1
700 "	"	800 "	6.9	1200 "	...	3/16"	55 "	..
675 "	"	900 "	6.9	1025 "	149 "	1/8 "	50 "	2.5
575 "	"	750 "	7.0	825 "	93 "	3/32"	..	2.0
650 "	"	700 "	6.8	1050 "	135 "	1/8 "	50 "	2.3
Av. 600 cc.	8.65	750 cc.	6.85	990 cc.	123 gms.	1/8 "	50 secs.	2.2

The settlings at this factory after being discharged from the continuous settlers are resettled. Even after resettling they are low in suspended solids. The filtration rate on the untreated settlings is a little below the average. There is only a slight response to lime and phosphoric acid, the filtration rate for the Borden-treated settlings being considerably below the average. A thin cake was formed, averaging only ⅛" in thickness, and cracking in 50 seconds. For a cake of this thickness this is a long cracking time, indicating a cake that is not very porous.

Filtration data of the settlings at Kekaha Sugar Company. Date of tests, April 4, 5, 6, 7, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
700 cc.	8.6	850 cc.	6.8	1100 cc.	150 gms.	1/8 "	50 secs.	2.4
675 "	8.7	900 "	6.9	1200 "	145 "	1/8 "	55 "	2.2
900 "	8.6	1180 "	6.8	1380 "	160 "	1/8 "	45 "	2.0
675 "	8.6	925 "	6.8	1300 "	200 "	3/16"	45 "	2.7
800 "	8.6	1050 "	6.8	1450 "	240 "	1/4 "	40 "	3.0
800 "	9.0	900 "	6.8	1100 "	192 "	3/16"	47 "	2.9
800 "	8.5	900 "	6.8	1100 "	180 "	3/16"	43 "	2.8
625 "	8.7	775 "	6.9	950 "	200 "	3/16"	50 "	3.5
710 "	8.7	950 "	6.8	1300 "	125 "	1/8 "	50 "	1.7
Av. 743 cc.	8.7	940 cc.	6.8	1210 cc.	177 gms.	3/16"	50 secs.	2.6

The filtration rate of the untreated settlings at this factory is higher than the average secured at Oahu Sugar Co. There is a fair response to lime and the phosphoric acid treatment. The filtration rate of the latter is somewhat less than the average. A cake averaging 3/16" in thickness and cracking in 50 seconds was formed. Such a long cracking time indicates that the cake is not very porous. The suspended solids in the settlings are fairly low; these will undoubtedly increase when the juices are settled in a Dorr clarifier.

Filtration data of the settlings at Hawaiian Sugar Company. Date of tests, May 18, 19, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
475 cc.	..	...	6.8	775 cc.	400 gms.	7/16"	35 secs.	6.6
675 "	8.6	750 cc.	6.8	1375 "	375 "	3/8 "	30 "	4.2
600 "	8.7	900 "	6.9	900 "	286 "	1/4 "	..	3.8
725 "	8.7	1025 "	6.9	1550 "	546 "	1/2 "	40 "	5.2
*1150 "	8.8	1480 "	6.8	1850 "	1000 "	1 "	30 "	7.0
*1050 "	..	...	6.7	1750 "	1250 "	1 1/4 "	40 "	8.3
Av. 779 cc.	8.7	1039 cc.	6.8	1370 cc.	643 gms.	5/8 "	35 secs.	6.0

By far the thickest settlings were found here at Hawaiian Sugar Company. The suspended solids in some samples were as high as 10 per cent. In this condition no tests could be made, so the writer diluted these settlings down to 7.0 to 8.0 per cent with hot clarified juice. The treated settlings on the average showed a very good filtration rate, besides forming a very thick cake, averaging 5/8". An individual sample was 1¼" in thickness. These thick cakes cracked in 35 seconds, indicating a highly porous condition.

Filtration data of the settlings at Makee Sugar Company. Date of tests, May 20, 21, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
885 cc.	8.5-8.8	1475 cc.	6.9	1200 cc.	97 gms.	1/8 "	37 secs.	1.5
475 "	"	800 "	6.8	750 "	350 "	3/8 "	..	6.3
1100 "	9.0	1325 "	6.8	1200 "	110 "	3/32"	35 "	1.6
700 "	8.5-8.8	1000 "	6.9	1030 "	128 "	1/8 "	40 "	2.2
685 "	"	1025 "	6.8	1085 "	152 "	1/8 "	..	2.4
720 "	"	1025 "	6.9	1125 "	158 "	5/32"	40 "	2.5
800 "	"	1000 "	6.7	1050 "	123 "	3/32"	35 "	2.1
Av. 766 cc.	8.5-8.8	1090 cc.	6.8	1060 cc.	160 gms.	5/32"	37 secs.	2.7

* Diluted with clarified juice.

The characteristics of the settlings are quite different from the average. The rate of flow of the untreated settlings is considerably higher than the average found at Oahu Sugar Co. When these settlings were limed to 8.5 to 8.8 pH, a good increase in filtration rate was secured, but when these limed settlings were acidified with phosphoric acid to 6.8 pH, a small decrease in filtration rate was secured. With the exception of one sample, these settlings are very thin or low in suspended solids. The one sample which ran over 6.0 per cent was taken after the boiling house was shut down for a few hours. Undoubtedly, with a more efficient type of settling tanks, thicker settlings could be secured. A fairly thin cake was formed, averaging 5/32″ in thickness and cracking in 37 seconds.

Filtration data of the settlings at Hawaiian Agricultural Company. Date of tests, June 1, 2, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
...	8.6	900 cc.	6.8	1025 cc.	133 gms.	1/8 ″	40 secs.	2.3
...	8.8	810 ʻʻ	6.8	1050 ʻʻ	175 ʻʻ	3/16″	..	2.8
800 cc.	9.0	1050 ʻʻ	6.9	1175 ʻʻ	140 ʻʻ	1/8 ″	45 ʻʻ	2.2
900 ʻʻ	8.7	1075 ʻʻ	6.8	1650 ʻʻ	400 ʻʻ	3/8 ″	40 ʻʻ	3.9
...	8.5-8.8	1000 ʻʻ	6.8	1075 ʻʻ	220 ʻʻ	7/32″	..	3.4
750 ʻʻ	8.5-8.8	750 ʻʻ	6.7	900 ʻʻ	190 ʻʻ	3/16″	..	3.4
725 ʻʻ	8.7	775 ʻʻ	6.8	900 ʻʻ	180 ʻʻ	3/16″	40 ʻʻ	3.3
Av. 794 cc.	8.8	910 cc.	6.8	1110 cc.	205 gms.	3/16″	41 secs.	3.0

The filtration rate of the untreated settlings at this factory was considerably higher than that found at Oahu Sugar Co. The filtration rate of the limed settlings is about normal, but on the acidified settlings the filtration rate is considerably less than the average. The cake averaged 3/16″ in thickness and the time of cracking was 41 seconds. The suspended solids in the settlings averaged 3.0 per cent during the time of these tests. This is the same as the average of the settlings for nineteen factories.

Filtration data of the settlings at Hilo Sugar Company. Date of tests, June 4, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
1150 cc.	8.7	1775 cc.	6.8	1675 cc.	173 gms.	7/32″	40 secs.	1.9
900 ʻʻ	8.5	1200 ʻʻ	6.7	1400 ʻʻ	327 ʻʻ	3/8 ″	35 ʻʻ	3.8
1050 ʻʻ	8.6	1700 ʻʻ	6.8	1700 ʻʻ	165 ʻʻ	3/16″	45 ʻʻ	1.8
1000 ʻʻ	8.7	1550 ʻʻ	6.9	1600 ʻʻ	200 ʻʻ	7/32″	35 ʻʻ	2.2
Av. 1025 cc.	8.6	1556 cc.	6.8	1600 cc.	218 gms.	3/16″	39 secs.	2.4

The average filtration rate of the untreated settlings at this factory is over 100 per cent higher than the average found at Oahu Sugar Company. When these settlings were limed to 8.6 pH the filtration rate increased to 1556 cc., which is considerably above the average for limed settlings. The treated settlings showed only a slight increase in the filtration rate. However, this is well above the average found at the various factories. The cake averaged 3/16″ in thickness and cracked in 39 seconds, indicating a fairly porous cake. The settlings are low in suspended solids.

Filtration data of the settlings at Waiakea Mill Company. Date of tests, June 6, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
...	9.0	800 cc.	6.8	780 cc.	240 gms.	1/4 ″	90 secs.	4.8
525 cc.	8.65	775 "	6.9	800 "	220 "	3/16″	110 "	4.3
675 "	8.6	750 "	6.8	750 "	151 "	1/8 ″	90 "	3.3
525 "	8.8	800 "	6.8	825 "	145 "	1/8 ″	85 "	3.0
Av. 575 cc.	8.8	781 cc.	6.8	789 cc.	189 gms.	3/16″	94 secs.	3.8

The settlings at this factory have the poorest filtering characteristics of any tested. There was a small response to lime and practically no further response when these settlings were acidified with phosphoric acid. The filtration rate of the treated settlings is about 40 per cent below the average found at Oahu Sugar Co. A cake 3/16″ in thickness and cracking in 94 seconds was formed on the test plate. The long time interval indicates that it is not porous. Considerable difficulty was experienced in handling these settlings in the filter presses. A high polarization in cake was secured. The settlings averaged 3.8 per cent suspended solids. This is 18 per cent higher than the average.

Filtration data of the settlings at Olaa Sugar Company. Date of tests, June 7, 8, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
750 cc.	8.5-8.8	800 cc.	6.8	1150 cc.	175 gms.	5/32″	45 secs.	2.6
650 "	"	950 "	7.0	1100 "	126 "	1/8 ″	50 "	2.0
700 "	"	800 "	6.8	1000 "	150 "	5/32″	45 "	2.6
...	9.0	800 "	6.9	950 "	178 "	3/16″	40 "	3.1
800 "	8.5-8.8	800 "	6.8	975 "	...	3/16″	..	..
650 "	"	875 "	6.8	975 "	260 "	7/32″	55 "	4.0
650 "	"	800 "	6.8	1000 "	...	7/32″	..	..
650 "	"	850 "	6.9	1075 "	160 "	3/16″	48 "	2.4
730 "	"	825 "	6.9	1100 "	220 "	7/32″	35 "	3.3
Av. 700 cc.	8.7	835 cc.	6.85	1036 cc.	181 gms.	3/16″	45 secs.	3.0

The response to lime and phosphoric acid treatment of these settlings was considerably below that usually found at the Oahu Sugar Co. The cake averaged only 3/16" in thickness and cracked in 45 seconds. This indicated that the cake was not very porous. The suspended solids in the settlings varied from 2.0 to 4.0 per cent, averaging 3.0 per cent. Considerable difficulty was experienced in handling these settlings in the filter presses, producing a press cake high in polarization. The characteristics of these settlings will be more fully discussed in another part of this report.

Filtration data of the settlings at Laupahoehoe Sugar Company. Date of test, June 9, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
1075 cc.	8.5-8.8	1275 cc.	6.7	1400 cc.	...	5/16"	..	..
1375 "	"	1400 "	6.8	1650 "	309 gms.	5/16"	25 secs.	3.1
1150 "	"	1375 "	6.9	1550 "	...	7/16"	..	..
1250 "	"	1400 "	6.8	1500 "	340 "	7/16"	25 "	4.2
1450 "	"	1500 "	6.8	1600 "	...	5/16"	..	..
Av. 1260 cc.	8.65	1390 cc.	6.8	1540 cc.	325 gms.	3/8 "	25 secs.	3.6

The filtration rate of the untreated settlings at this factory is almost 200 per cent greater than that found at Oahu Sugar Co. While there is only a small response to lime and phosphoric acid, the filtration rate of the limed settlings, as well as the treated settlings, are both higher than the average. The cake averaged ⅜" in thickness and cracked in 25 seconds. Such a cake is very porous and can be easily sweetened off. Exceptionally low polarizations in press cake have been reported from this factory.

The cane at this factory is all flumed to the mill. At the time of this visit, the cane was very clean and practically free from trash. The absence of the soil and trash in this cane undoubtedly explains the exceptionally good filtration characteristics of these settlings.

Filtration data of the settlings at Honokaa Sugar Company. Date of tests, June 10, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
...	9.0	1750 cc.	6.8	1350 cc.	170 gms.	3/16"	25 secs.	2.2
1175 cc.	8.8	1375 "	6.8	1425 "	235 "	1/4 "	30 "	2.8
875 "	9.0	1500 "	..	....	...	...	..	..
1650 "	8.8	1930 "	6.8	1600 "	152 "	3/16"	23 "	2.2
500 "	8.65	830 "	6.8	1200 "	100 "	3/32"	35 "	1.5
Av. 1050 cc.	8.9	1477 cc.	6.8	1394 cc.	164 gms.	3/16"	30 secs.	2.2

The filtration characteristics of the settlings at this factory are of two distinct types. The one, which is typical of many factories, has a low filtration rate on the untreated settlings and responds to both lime and phosphoric acid treatment, yielding an increase in filtration rate in the limed settlings and a further increase in the treated settlings.

The other type has filtration characteristics similar to those found at Makee Sugar Co. A high filtration rate is secured on the untreated settlings and a fair increase in filtration rate in the limed settlings, but the acidified settlings show a decrease in filtration rate. The cake averaged 3/16″ in thickness and cracked in 30 seconds, indicating a high degree of porosity.

Filtration data of the settlings at Hawi Mill and Plantation Co. Date of tests, June 14, 15, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
575 cc.	8.5-8.8	850 cc.	6.7	925 cc.	150 gms.	1/8 ″	45 secs.	2.8
950 "	"	1050 "	6.8	1175 "	145 "	1/8 ″	50 "	2.2
850 "	"	1000 "	6.8	1100 "	163 "	5/32″	45 "	2.6
950 "	"	1100 "	6.9	1110 "	155 "	5/32″	50 "	2.4
Av. 831 cc.	8.5-8.8	1000 cc.	6.8	1080 cc.	153 gms.	5/32″	48 secs.	2.5

A fairly high filtration rate was secured on the untreated settlings at this factory. The average of four tests was approximately 90 per cent higher than that generally found at Oahu Sugar Co. A fair increase in the filtration rate was found in the limed settlings. In the treated settlings the filtration rate was increased only slightly. The average is about 25 per cent below the average for treated settlings at Oahu Sugar Co. The cake averaged 5/32″ in thickness and cracked in 48 seconds. The suspended solids in the settlings were only 2.5 per cent, but they were fairly uniform in density.

The filtration data from the various factories have been classified into six groups. While there are some variations within each classification, the filtration characteristics of the settlings in each group have some specific difference from the other groups.

Factory	Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS						
	Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings	Fiber % cake solids
Oahu	440 cc.	8.7	874 cc.	6.8	1375 cc.	360 gms.	3/8 "	30 secs.	4.1	33.3
Honolulu	475 "	8.6	875 "	6.8	1167 "	245 "	1/4 "	32 "	3.45	27.9
Pioneer	492 "	8.9	885 "	6.8	1715 "	420 "	7/16"	28 "	3.6	44.6
GROUP I Average	469 cc.	8.7	878 cc.	6.8	1419 cc.	342 gms.	3/8 "	30 secs.	3.7	35.3
Ewa	(900 cc.)	8.8	900 cc.	6.9	1260 cc.	131 gms.	1/8 "	48 secs.	1.8	14.8
Waialua	710 "	8.8	845 "	6.8	1300 "	183 "	3/16"	45 "	2.45	20.6
Kahuku	730 "	8.7	900 "	6.8	1130 "	195 "	5/32"	36 "	2.9	25.0
Kekaha	743 "	8.7	940 "	6.8	1210 "	177 "	3/16"	50 "	2.6	20.0
H. S. Co.	779 "	8.8	1039 "	6.8	1370 "	643 "	5/8 "	35 "	6.0	38.0
H. A. Co.	794 "	8.8	910 "	6.8	1110 "	205 "	3/16"	41 "	3.0	27.3
Olaa	700 "	8.65	834 "	6.85	1036 "	181 "	3/16"	45 "	3.0	21.0
GROUP II Average	743 cc.	8.75	910 cc.	6.83	1202 cc.	245 gms.	1/4 "	43 secs.	3.1	23.8
Laupahoehoe	1260 cc.	8.65	1390 cc.	6.8	1540 cc.	325 gms.	3/8 "	25 secs.	3.6	39.6
Hilo	1025 "	8.6	1556 "	6.8	1600 "	218 "	3/16"	39 "	2.4	45.7
Hawi	831 "	8.65	1000 "	6.85	1080 "	153 "	5/32"	48 "	2.5	26.1
GROUP III Average	1039 cc.	8.63	1315 cc.	6.82	1407 cc.	232 gms.	1/4 "	37 secs.	2.8	37.1
Honokaa	1050 cc.	8.9	1477 cc.	6.8	1394 cc.	164 gms.	3/16"	30 secs.	2.2	26.3
Makee	766 "	8.65	1090 "	6.8	1060 "	160 "	5/32"	37 "	2.7	15.5
GROUP IV Average	908 cc.	8.78	1283 cc.	6.8	1227 cc.	162 gms.	11/64"	33.5 secs.	2.45	20.9
Lihue	600 cc.	8.65	750 cc.	6.85	990 cc.	123 gms.	1/8 "	56 secs.	2.6	21.2
Wailuku	700 "	8.8	800 "	6.8	925 "	109 "	7/64"	51 "	2.1	18.5
GROUP V Average	650 cc.	8.72	775 cc.	6.82	958 cc.	116 gms.	7/64"	53.5 secs.	2.35	19.9
M. A. Co.	795 cc.	8.7	825 cc.	6.85	985 cc.	140 gms.	3/32"	56 secs.	2.6	3.0
Waiakea	575 "	8.8	781 "	6.8	789 "	189 "	3/16"	94 "	3.8	11.5
GROUP VI Average	685 cc.	8.75	803 cc.	6.82	887 cc.	164 gms.	5/32"	75 secs.	3.2	7.25
AVERAGE OF ALL	748 cc.	8.65	983 cc.	6.8	1212 cc.	227 gms.	7/32"	44 secs.	3.0	25.3

In the first group of factories we have Oahu Sugar Co., Honolulu Plantation Co., and Pioneer Mill Co. The filtration rate of the untreated settlings is very low. The average for the three factories is 469 cc. After liming to 8.7 pH, the filtration rate of the settlings is increased to 878 cc. This amounts to an increase in filtration rate of 87 per cent. The phosphoric acid treated settlings show a further increase in filtration rate amounting to 110 per cent of the rate for untreated settlings. At each of these factories a thick cake was formed, averaging 3/8" in thickness. The average time of cracking is 30 seconds, indicating a high degree of porosity.

The settlings at all three of these factories are suited to an Oliver Continuous Filter.

There are seven factories in the second group. These are as follows: Ewa Plantation Co., Waialua Agricultural Co., Kahuku Plantation Co., Kekaha Sugar Co., Hawaiian Sugar Co., Hawaiian Agricultural Co., Olaa Sugar Co. The chief differences in the characteristics of this group over the first group are the higher filtration rates on the untreated settlings, averaging 743 cc. as against 469 cc. The filtration of the limed settlings is 910 cc., which is close to that of the first group. When the settlings are acidified, the average filtration rate is 1202 cc. This is considerably smaller than the filtration rate of the first group. While the average thickness of cake for this group is 1/4", this is due to the exceptional thickness of the cake at Hawaiian Sugar Co. If this one factory is omitted, the average becomes 11/64". The average time of cracking is 43 seconds, indicating that the cake is fairly porous. The per cent suspended solids in the settlings for this group is influenced by the high figure for Hawaiian Sugar Co. With this factory included, the average is 3.1 per cent; without, it is 2.6 per cent. Of the group, the settlings at Hawaiian Sugar Co. have characteristics which are best suited to an Oliver filter. The high filtration rate, 1370 cc. on acidified settlings, the cake 5/8" in thickness and a cracking time of 35 seconds, are all characteristics favorable to a continuous filter.

The settlings at Olaa Sugar Co. have the poorest characteristics of any in the group. The filtration rate of the untreated settlings, limed settlings and Borden treated settlings is 700 cc., 834 cc., 1036 cc. respectively. The cake averaged 3/16" in thickness and cracked in 45 seconds, indicating only a fair degree of porosity.

With the exception of Hawaiian Sugar Co., the settlings at the other factories were not suited to an Oliver filter. The chief deficiency in each case was the amount of fiber or cush cush present in the suspended solids. A discussion of the concentration of the fiber in the suspended solids in settlings necessary to secure good results on an Oliver filter is presented in another part of this report.

In the third group are three factories: Laupahoehoe Sugar Co., Hilo Sugar Co., Hawi Mill & Plantation Co. The average filtration rate of the untreated settlings in this group is 1039 cc. This is over 120 per cent more than the average for the first group. The limed settlings show an increase in filtration rate which is also considerably higher than that found in either the first or second groups. The filtration rate of the Borden treated settlings shows only a fair increase: the average is slightly below that of the first group. The outstanding characteristics of the

settlings in this group are the high filtration rates on the untreated settlings, the fairly large increase due to liming the settlings, and the comparatively small increase in filtration rate when treated with phosphoric acid. The cake averaged ¼″ in thickness and cracked in 37 seconds.

Of the three factories in this group, the filtration characteristics of the settlings at the Laupahoehoe Sugar Co. are the best of any settlings tested. The writer is of the opinion that at times these settlings would be successfully filtered on an Oliver filter without any treatment, or only a partial treatment.

The characteristics of the settlings at Hilo Sugar Co. are such that it is doubtful whether they could be handled on an Oliver filter without some modification. Even though the per cent fiber in the suspended solids is well above 30 per cent, the concentration of the suspended solids in the settlings is very low at times. This would produce a cake on an Oliver filter which would be too thin to handle satisfactorily. For this reason a longer cycle on the Oliver filter might be required.

The fiber content of the settlings at Hawi Mill & Plantation Co. would have to be increased to make them suited for an Oliver filter.

In the fourth group are two factories: Honokaa Sugar Co., Makee Sugar Co. The chief characteristics of these settlings are the relatively high filtration rate of the untreated settlings and the decrease in filtration rate of the treated settlings from the filtration rate of the limed settlings. These are the only two instances where this occurs.

The average filtration rate of the untreated settlings is 908 cc. This is almost 100 per cent higher than that of the first group and only about 10 per cent lower than that of the third group, which has the highest filtration rate on untreated settlings of any tested. After liming and then treating with phosphoric acid the rates were 1283 cc. and 1227 cc. respectively, showing a decrease of 56 cc. While this decrease is small, it is, nevertheless, interesting. The cake averaged 11/64″ in thickness and cracked in 33.5 seconds, indicating a porous cake. The settlings at these factories could be handled on an Oliver filter, provided the fiber content in the cake solids was increased to the proper concentration.

In the fifth group are two factories: Lihue Plantation Co. and Wailuku Sugar Co. While the average filtration rate of untreated settlings is 650 cc., the limed settlings and treated settlings have the respective filtration rates 775 cc. and 958 cc. The failure to respond to any great extent to liming or to treating with phosphoric acid is the chief characteristic of these settlings. An exceptionally thin cake was formed in both cases, averaging 7/64″ in thickness and cracking in 53.5 seconds. This is an unusually long time interval for such a thin cake, indicating that the cake was not very porous. The filtration characteristics of these settlings would have to be improved considerably to make them suitable for an Oliver filter.

In the sixth group are Maui Agricultural Co. and Waiakea Mill Co. It is largely because the settlings at these two factories are extremely low in fiber that they were grouped together. The filtration rate of the untreated settlings is slightly more than the previous group, and is almost 50 per cent higher than the first group. But the response to lime and acid is very low, resulting in a filtration rate of 803 cc. for limed settlings and 887 cc. for treated settlings. This latter figure is the

lowest of any group average, being 60 per cent of the maximum which is found in the first group. The cake averaged 5/32″ in thickness, with an average cracking time of 75 seconds, indicating that the cake was not porous. The filtration characteristics of the settlings at both these factories are unsuited for an Oliver filter. The fiber content would have to be increased to the proper concentration.

The main reason why the settlings in the majority of the factories visited are not suited to an Oliver filter in its present application in cane sugar factories is because the fiber in the suspended solids is too low. When the settlings contain 3 per cent or more suspended solids, it has been found that the fiber should be at least 28 to 30 per cent of the suspended solids. This is equivalent to approximately .9 to 1.0 per cent on the settlings. In numerous tests at Waipahu, it was observed that as the fiber content decreases below 28 to 30 per cent of the suspended solids, the settlings become more difficult to handle on the Oliver filter. The capacity is decreased, the polarization of the cake as discharged is increased, and the frequency with which the cloth must be washed is increased.

The data secured at Hilo Sugar Company indicate that as the per cent suspended solids in the settlings decreases below 3.0 per cent, the per cent fiber in the suspended solids must be increased. From this it seems that the fiber concentration should be at least 1.0 per cent of the settlings, when the suspended solids in the settlings are 3.0 per cent or less. With concentrations of suspended solids greater than 3.0 per cent, the fiber should be, as previously mentioned, 28 to 30 per cent of the suspended solids.

The reason for this is that when the settlings contain less than 3.0 per cent suspended solids, a concentration of fiber of 1.0 per cent on settlings is necessary to secure a cake of suitable thickness and porosity on the Oliver filter.

Oliver Filter Operation at Olaa:

During the past year (1928) an Oliver filter was installed at the Olaa Sugar Company. It was ready for operation on April 7. The filtration tests made on the settlings at Olaa in June, 1927, indicated that the per cent fiber in the cake solids would have to be increased in order to secure satisfactory results on the Oliver filter. In order to verify these predictions, attempts were made to operate the filter on these settlings before any change in the mill screens was made. At this time a No. 4 screen, having 225 perforations per square inch, was in use. This is the same size screen that was used last year. The results on the Oliver filter were not satisfactory when these settlings were filtered. The capacity was low, the cake was thin and difficult to sweeten off. After a few hours running it was necessary to stop and wash the cloth. The fiber in the cake solids was only 18.5 per cent. These results coincide perfectly with the writer's prediction a year ago.

A No. 7 screen, having 144 perforations per square inch, was then installed to replace the No. 4 screen. This increased the fiber content to 23.5 per cent on cake solids. There was some improvement both in capacity as well as thickness of cake, but the results were still unsatisfactory. A No. 10 screen, having 64 perforations per square inch, was then installed. With the installation of this coarser screen the fiber in the cake solids was increased to 29 per cent and corrected all the

difficulties which had been encountered. The capacity was increased to a point which may be considered satisfactory, approximately 250-300 cubic feet per hour. The cake was between ¼" and ½" in thickness and was sufficiently porous so that it could be sweetened off to a reasonable polarization.

Commencing Sunday night, April 22, the Oliver filter became an integral part of the filter press station. During the first week the filter averaged approximately 55 per cent of all the settlings, amounting to 5500 cubic feet of settlings in 24 hours. This is equivalent to 38 tons cane per hour. The average polarization was 1.28 per cent. The second week that the filter was in continuous operation the capacity dropped to approximately 4500 cubic feet per day, corresponding to about 45 per cent of the total settlings, equivalent to 31.5 tons cane per hour. The main reason for this reduction in capacity was that the fiber content in the cake solids was only 23-26 per cent. There was a large proportion of D 1135 cane ground during the week. The fiber in this cane does not produce as much cush cush as other varieties of cane do.

There is another factor which influenced the capacity of the filter; the cloth with which the drum was covered was too heavy. A heavy cloth will produce a very clear filtrate, but the capacity is less than when a more open cloth is used. It is also more difficult to keep it clean. It is more than likely that there is a gradual accumulation of small particles in the cloth which cannot be removed by scrubbing with brushes.

During the third week, the Oliver filter was covered with a lighter weight cloth. Mr. Giacometti informed the writer that the settlings, corresponding to 120 tons of sugar per day (24 hours), were handled by the Oliver filter. This is equivalent to 6600 cubic feet of settlings, or 48 tons cane per hour.

This work at Olaa has shown quite conclusively that while the filtration characteristics of settlings may be unsuited for an Oliver filter, they can be improved and made suitable by increasing the per cent fiber in the suspended matter in the mixed juice. In this particular case, a sufficient amount of fiber could be introduced in the mixed juice by simply using coarser screens in the drag conveyor. The question arises whether under all conditions there will be sufficient fiber in a fine state of division formed so that this simple expedient will prove satisfactory.

There are a number of factors which tend to influence this: these are, the milling equipment, the variety of cane, and the condition of the cane. For any given variety of cane, it seems that a mill equipped with a shredder will produce more cush cush than a mill without a shredder. The grooving and the pressure on the rolls also influence the quantity of cush cush that is formed.

With the same milling equipment, different varieties of cane will produce varying amounts of cush cush. For example, D 1135 produces less cush cush than either H 109 or Yellow Caledonia. The same variety of cane will produce more cush cush in the summer months than in the winter months. The reason for this is that the fiber in the cane becomes more brittle in the dry weather. These factors all tend to influence the amount of cush cush which is formed. It is for these reasons that the writer hesitates to state definitely that by changing the size of the mill screen, sufficient fiber can always be added to the mixed juice so the filtration characteristics of the settlings will be suited for an Oliver filter.

An Explanation of the Reactions Which Take Place During the Borden Process of Treating Settlings:

Data are presented in the following pages in an attempt to explain the reactions which take place when settlings are subjected to the Borden treatment. In the filtration tests on untreated settlings we do not find any correlation between the volume of filtrate and the per cent fiber in the suspended solids. For example, the untreated settlings at Oahu Sugar Company had a filtration rate of 440 cc., and at Laupahoehoe Sugar Company a filtration rate of 1300 cc. The fiber in the suspended solids at Oahu Sugar Company is 33.3 per cent, while at Laupahoehoe it is 39.6 per cent. Both of these are high in fiber, yet before treatment the settlings at Oahu have the lowest filtration rate of any tested, while the settlings at Laupahoehoe have the highest filtration rate. After they have been treated by the Borden process the filtration rates are practically the same. The settlings at Oahu show a large increase in filtration rate, while the settlings at Laupahoehoe Sugar Company show only a small improvement.

In view of the above data, it is quite logical to conclude that some substance or substances are present in the Oahu settlings in greater concentrations and that they retard filtration. Further, by the Borden treatment their physical or chemical properties are changed so they do not retard filtration.

The filtration data secured at the various factories have shown that on untreated settlings from flumed cane, a very much greater filtration rate will be secured than on the untreated settlings from non-flumed cane. The settlings at Laupahoehoe Sugar Company contain more ether-soluble matter, such as cane wax, etc., than the settlings at Oahu. From this fact it does not seem possible that the ether-soluble matter entered into the reaction. The writer has never been able to establish any correlation between the ether-soluble content and the filtration characteristics of settlings.

There is a difference in the appearance of the settlings at Oahu and Laupahoehoe. The untreated settlings at Oahu Sugar Company resemble a smooth, creamy mass. The suspended particles appear to have lost their individual form and seem to be diffused in a gelatinous substance. After treatment, the particles regain their individual form. At Laupahoehoe, the suspended particles in the untreated settlings have not lost their individual form. In appearance they resemble the settlings at Oahu Sugar Co., after treatment.

It occurred to the writer that a study of the inorganic salts in press cake might explain the reactions which occur during the Borden treatment. The most important inorganic components in press cake are iron (Fe), aluminum (Al), calcium (Ca) and magnesium (Mg). The salts are phosphates, sulphates, hydroxides, aluminates, silicates and salts of organic acids. Besides these simple combinations there are undoubtedly more complex forms in which Fe, Al and silica are combined. There may be several forms of silica present. It is because of these possible variations, both in chemical composition as well as physical conditions, that the orthodox methods of procedure in solving a problem could not be followed.

The writer studied the effect on filtration rate when varying amounts of inorganic salts, assumed to be present, were added to the settlings. Considerable

preliminary work was done in which the data were inconsistent. The reason for this was because the salts were either sufficiently acid or alkaline to produce changes in the pH of the settlings. To correct this, these salts were neutralized until the pH was about the same or close to that of the settlings. Only small amounts of these salts were added in order to approximate actual concentrations. The following tabulation gives the list of salts and the concentrations of the solutions used.

Salt Solutions	Gms. Salt per Liter	Gms. per cc.
Ferric chloride $FeCl_3$	81.11	.0279 Fe
Aluminum chloride $AlCl_3$..........	66.74	.0136 Al
Sodium aluminate.................	82.1	.051 Al_2O_3
Sodium silicate...................	61.1	.030 SiO_2
Magnesium chloride...............	95.24	.024 Mg
Potassium hydrogen phosphate....	87.125	.071 P_2O_5
Calcium chloride..................	27.75	.010 Ca

In the series of tests given below the settlings were limed to 8.5 to 8.7 pH and then double superphosphate was added until the pH was reduced to about 7.4 pH. This was done so that almost the maximum rate of flow of settlings would be secured, and yet the pH would be approximately the same as that in the untreated settlings. With a high rate of flow the writer believed that more pronounced effects would be secured by the addition of these salts. In all tests 1300 cc. of settlings were used. The amount of salt solution and resulting concentration are given in the tabulation.

Test No.	Salt Solutions Added	Conc. % Settlings	Vol. of Filtrate
1	Blank (1300 cc. of settlings)	...	1225 cc.
2	" + 20 cc. $FeCl_3$	.043% Fe	1200 cc.
3	" + 40 cc. "	.086% Fe	1240 cc.
4	" + 40 cc. $AlCl_3$	.041% Al	1180 cc.
5	" + 80 cc. "	.083% Al	1210 cc.
6	" + 50 cc. $CaCl_2$	.039% Ca	1225 cc.
7	" + 100 cc. "	.078% Ca	1200 cc.
8	" + 25 cc. $MgCl_2$	.046% Mg	1195 cc.
9	" + 50 cc. "	.092% Mg	1200 cc.
10	" + 25 cc. Na_2SiO_3	.058% SiO_2	120 cc.
11	" + 50 cc. Na_2SiO_3	.116% SiO_2	100 cc.
12	" + 10 cc. $Na_2Al_2O_4$	.041% Al_2O_3	1175 cc.
13	" + 20 cc. "	.08 % "	1195 cc.
14	" + {20 cc. $Na_2Al_2O_4$ 25 cc. Na_2SiO_3	{.083% Al_2O_3 .058% SiO_2	1200 cc.

Inspection of the above tabulation shows that sodium silicate added to the settlings reduced the filtration rate from 1225 cc. to 120 cc. This sodium silicate was first acidified to about 7.5 pH and then added to the settlings. In view of the very pronounced retarding effect produced by this silicate, the writer studied this salt exclusively.

Sodium silicate in a water solution gives an alkaline reaction to phenolphthalein. When it is neutralized it first forms an acid silicate ($NaHSiO_3$). This salt in itself does not form any gelatinous precipitate in distilled water in the concentra-

tions used. However, in the presence of calcium hydroxide or magnesium hydroxide a voluminous and gelatinous precipitate is formed, and when mixed with cush cush it forms this cream-like mass resembling settlings before treatment.

Some of this gelatinous precipitate formed in clarified juice had a volume of 150-200 cc. When it was dried, it weighed only two grams, indicating a very great water-holding capacity, capable of covering a large surface. An analysis of this precipitate after drying showed that it contained 92 per cent silica (SiO_2). As there is no known silicate that contains such a large proportion of SiO_2, the writer has concluded that the precipitate consists largely or $SiO_2 \times H_2O$, and that the other substances present are simply occluded during its formation.

When this precipitate is formed in clarified juice and then is subjected to the Borden treatment, there is a gradual disappearance of the slimy, gelatinous precipitate, until, at 6.8 pH and below, there is no evidence of any being left.

A few tests were made to determine whether the silica in the settlings was redissolved when subjected to the Borden treatment. Samples were taken of the filtrate from untreated settlings, after liming and after the Borden treatment. If the silica was redissolved, then it was expected to be found in the filtrate.

	Silica % Ash in Filtrate	Ash % Filtrate	SiO_2 % Filtrate
Untreated settlings................	5.60	.41	.02
Limed settlings....................	2.27	.43	.01
Acidified settlings.................	6.78	.44	.03

The silica shows an increase of .02 per cent in the filtrate from the treated settlings. Approximately 12.5 per cent of the silica in the settlings is redissolved by the Borden treatment. This percentage will vary greatly, depending on the type of silica present in the settlings. In the experiments conducted by the writer it was found that by adding very small amounts of silica under certain conditions, the filtration rate could be reduced considerably below any found. The data in this experiment indicate that there is a re-solution of silica when the settlings are acidified with phosphoric acid.

Another test was made in which samples were taken of the mixed juice, filtered mixed juice, filtered hot limed mixed juice, clarified juice, and the settlings both before and after treatment.

	SiO_2 % Ash	Ash % Juice	SiO_2 % Juice
Mixed juice.......................	13.6	.38	.052
Filtered mixed juice...............	2.5	.29	.007
Filtered hot limed mixed juice......	3.97	.30	.012
Clarified juice....................	4.2	.31	.013
Filtrate untreated settlings........	5.45	.32	.017
Filtrate limed settlings............	1.35	.35	.005
Filtrate acidified settlings..........	6.62	.33	.022

These analyses show that a large part of the silica in the mixed is in the suspended matter. During clarification a part goes into solution. In the settlings we have the same effect as noted in the previous experiment.

The writer has concluded that the more soluble silicates in the juices and suspended matter are transformed during the clarification process into this gelatinous form of silica. The important points have been summarized as follows:

A comparatively small quantity of the gelatinous silica has a very pronounced retarding effect on the filtration rate. Small quantities, representing only a part of

what is in settlings, will produce a filtration rate which is very much less than has been found in the poorest of settlings.

There is a close similarity to settlings in its behavior toward phosphoric acid. As the pH of the settlings is reduced from 8.5, there is a gradual disappearance, until, at 6.8 pH, there seems to be a complete disappearance.

This silica gel will form in the pH range encountered in clarification, and also at these temperatures and concentrations.

Were it possible to separate the various forms of silica or silicates in settlings, more direct data could be secured to substantiate or disprove this theory.

Filter Press Performance As Influenced By Fiber-Silica Ratio

As a part of the survey made on the filtration characteristics of the settlings, samples of press cake were collected from each of the factories. From these analyses, and also from the observations made at each factory, the writer wished to determine whether there were any outstanding differences in composition which would affect the filter press work.

The work at Oahu Sugar Company has shown the importance of fiber as a filter aid and cake former, and its value in producing a porous cake. Recent research work indicates that soluble silicates can be converted into a gelatinous condition during the clarification process. In this gelatinous condition the results show that it has a very pronounced retarding effect on filtration.

With this in mind, the writer determined fiber, ether-soluble, ash and silica on these press cake samples. The results were calculated to a sucrose-free, moisture-free basis. The ratio of fiber to silica has also been calculated, and in the tabulation which follows the data have been arranged according to this ratio. The sample of press cake having the highest ratio is first, and so on down. Settlings possessing the most favorable filtration characteristics would be in the upper portion of this table, while those with the poorest characteristics would be found in the lower portion of the table.

Per Cent Cake Solids

Factory	Fiber	Ether-Soluble	Ash	Silica	Fiber/Silica
Pioneer	44.6	12.7	18.0	2.2	20.3
Laupahoehoe	39.6	12.8	15.5	2.14	18.5
Hilo	45.7	10.9	19.7	4.10	11.1
Hawi	26.1	7.5	38.3	3.2	8.1
Oahu	33.3	11.3	26.8	4.9	6.7
Haw. Sugar	38.0	17.8	29.6	5.76	6.6
Makee	15.5	8.9	35.6	2.40	6.6
Honolulu Plt. Co.	27.9	13.8	32.7	4.67	6.0
Wailuku (July sample)	24.5	11.9	27.4	4.25	5.8
Ewa	14.8	9.7	32.6	2.60	5.7
Haw. Agr.	27.3	10.6	28.0	4.9	5.6
Waialua	20.6	7.9	28.9	4.92	4.2
Honokaa	26.3	8.2	41.0	6.72	3.94
Olaa	21.0	8.3	17.7	5.66	3.7
Kahuku	25.0	6.9	43.4	7.51	3.33
Kekaha	20.0	...	30.0	6.93	2.89
Wailuku (May sample)	18.5	9.4	35.2	6.72	2.77
Lihue	21.2	9.3	38.4	7.80	2.72
Waiakea	11.5	6.5	39.6	4.60	2.40

There are several other factors beside the filtration characteristics of the settlings which affect the filter press work. These are as follows: the filter press capacity available, the mechanical condition of the filter presses as well as the thickness of cake formed, the method of operation and the personal supervision. In view of all these factors, it is very difficult to compare the filter press work at the various factories on the basis of their filtration characteristics alone. Nevertheless, the above tabulation is very interesting, because in the upper half we find factories that are known to have good filtering settlings, while in the lower half are those known to have more or less difficult filtering settlings.

The writer had the opportunity to study the filtration characteristics of the settlings at Wailuku Sugar Co. during May and also July, 1927. To filter these settlings saisfactorily in May, excessive quantities of lime were used, while in July the settlings were filtered satisfactorily without the use of any extra lime. The analysis of the press cake shows a marked difference in the fiber/SiO_2 ratio.

	Per Cent Cake Solids			
	Fiber	Ash	Silica	Fiber/Silica
May sample	18.5	35.2	6.72	2.77
July sample	24.5	27.4	4.25	5.80

While the per cent fiber in the July sample has increased only 33 per cent, the fiber/SiO_2 ratio has more than doubled. This, the writer believes, accounts for the difference in the cake-forming properties.

According to Mr. Henderson, of the Lihue factory, the settlings at Lihue are very much more difficult to filter than at Makee. Lihue has 97 square feet of filtering surface, while Makee has 84 square feet filtering surface per ton cane per hour. This favors Lihue. An analysis of the press cake samples from these two factories follows:

	Per Cent Cake Solids			
Factory	Fiber	Ash	Silica	Fiber/SiO_2
Lihue	23.2	38.4	7.79	2.98
Makee	15.5	35.6	2.40	6.46

The press cake sample from Makee had only two-thirds of the fiber content of that from Lihue. However, the silica in the cake solids was only 30 per cent, which made the fiber/SiO_2 ratio for the press cake from Makee more than double that of Lihue. This difference in the fiber/SiO_2 seems to explain why the settlings at Makee can be filtered more readily than those at Lihue.

The data presented in a previous report, and also this report, have demonstrated that the fiber in the settlings serves as a cake-forming material as well as a filter aid; that some forms of silica can be converted into a gelatinous condition, and in this condition have a very pronounced retarding effect on filtration. This effect is more pronounced in some settlings than in others and can be corrected by treating the settlings with the Borden process. The ratio of the fiber to silica may serve as an index to differentiate between settlings having good filtration characteristics and settlings having poor filtration characteristics.

Acknowledgments

The writer is indebted to the managers and the personnel at these factories for their cooperation in carrying out the tests.

Annual Synopsis of Mill Data—1928

By W. L. McCleery

This Synopsis includes data from the forty factories of the Association. It represents all sugar produced from October 1, 1927, to approximately September 30, 1928, amounting to 897,416 tons, or an increase over the previous year of about 12 per cent. This calendar year does not coincide with the crop year for several factories. Figures for seven factories include portions of the previous crop ground after September 30, 1927. Five factories had not finished their 1928 crop on October 1, and one factory had started on its 1929 crop. Marks identifying these factories are shown in the first of the large tables.

There is very little change in the form of the Synopsis from that of last year. Data for roller grooving and returner bar settings, omitted the past two years, have been included in the large tables. The factories are listed in the tables in the order of their average sugar tonnage for the five previous years, unless otherwise noted.

Varieties of Cane

The major varieties of cane, ground to the extent of 1 per cent or more of the total crop, are shown in Table 1; also the ratio of individual varieties to the total crop for the past eleven seasons.

It will be noted that there are now only five major varieties. Lahaina and Striped Mexican have decreased to well under 1 per cent, and are now included in the tabulation of minor varieties. There has been a moderate increase in H 109, bringing its percentage up to 54.7, with its nearest competitor, Yellow Caledonia, showing a further decline to 20.7 per cent. D 1135, Yellow Tip, and Striped Tip have increased slightly. The general trend of the present five major varieties is the same as for several years.

With regard to the passing of Lahaina cane from the list of major varieties it may be mentioned that in 1918, the first year that this tabulation was started, Lahaina comprised 37.9 per cent of the total crop, and H 109, 4 per cent. During the next six years Lahaina was rapidly replaced by H 109, so that in 1924 Lahaina had decreased to 4.4 per cent of the crop, and H 109 had increased to 38.1 per cent. Last year the percentage of Lahaina was only 1.4 and this year it is .63 per cent. Striped Mexican, the other variety dropped from Table 1, never reached a high percentage, the highest being 3.1 in 1923. Since then the decline has been consistent to a low figure of .58 this year.

TABLE NO. 1
MAJOR VARIETIES OF CANE
(One per cent or more of total crop)

	H 109	Y. C.	D 1135	Yellow Tip	Striped Tip	Others
H. C. & S. Co.	99	..	1	..	..	..
Oahu	97	..	3	..	..	..
Ewa	100	..	..	..	..	..
Waialua	81	..	17	..	..	2
Maui. Agr.	91	..	..	..	..	9
Pioneer	92	..	1	..	..	7
Olaa	..	87	13	..	..	..
Haw. Sug.	91	..	8	..	..	1
Lihue	60	7	6	14	..	13
Honolulu	99	..	..	..	..	1
Onomea	..	80	3	16	..	1
Hilo	..	90	8	2	..	..
Kekaha	80	..	5	..	..	15
Haw. Agr.	..	39	49	..	..	12
Wailuku	91	..	4	..	..	5
Hakalau	..	74	3	23	..	..
Makee	56	17	..	16	..	11
Honokaa	3	6	81	..	..	10
McBryde	74	3	10	1	1	11
Laupahoehoe	..	32	37	31	..	..
Kahuku	91	8	..	..	..	1
Hamakua	..	20	72	8	..	..
Pepeekeo	..	86	6	8	..	..
Paauhau	3	1	77	17	..	2
Koloa	61	..	..	37	..	2
Honomu	..	94	4	..	..	2
Waiakea	..	97	2	..	..	1
Hawi	5	..	24	..	67	4
Hutchinson	..	55	19	..	..	26*
Kaiwiki	..	23	62	4	6	5
Waimanalo	95	1	3	..	..	1
Kohala	1	7	29	21	29	13
Kilauea	7	7	3	50	6	27†
Waianae	100	..	..	..	..	..
Kaeleku	..	100	..	..	..	..
Union Mill	..	5	8	..	87	..
Halawa	..	13	44	..	27	16
Niulii	..	26	37	27	10	..
Waimea	93	..	..	..	..	7
Olowalu	87	..	..	..	..	13
True Average 1928	54.7	20.7	12.9	4.9	2.2	4.6
" " 1927	53.1	23.7	11.8	4.0	1.6	5.8
" " 1926	48.7	25.6	12.1	4.5	2.1	7.0
" " 1925	42.7	30.7	11.9	2.7	2.1	9.9
" " 1924	38.1	32.6	12.0	2.3	2.0	13.0
" " 1923	30.7	36.3	11.2	1.2	1.6	19.0
" " 1922	21.1	40.3	12.2	2.7	1.6	22.1
" " 1921	15.0	45.1	11.0	1.2	1.8	25.9
" " 1920	9.1	42.7	10.0	1.4	2.1	34.7
" " 1919	6.8	46.4	7.2	0.3	2.6	36.7
" " 1918	4.0	42.9	7.5	0.5	1.5	43.6

* Rose Bamboo.
† Principally Badila.

MINOR VARIETIES

One Per Cent or More of the Crop at Any Factory

Variety	1924	1925	1926	1927	1928
Lahaina	...	...	...	...	.63
Striped Mexican	...	...	...	...	.58
Uba	.03	.11	.10	.13	.51
Rose Bamboo	...	...	...	.32	.40
Badila	.46	.35	.47	.37	.27
H 456	...	.11	...	.21	.14
Kohala Seedlings	...	...	.07	.08	.13
Wailuku Seedlings	...	...	.02	.07	.08
U. D. 1	...	...	...	.32	.07
D 117	.49	.52	.15	.25	.05
McBryde 1	...	...	...	...	.02
H 349	...	...	...	...	.01

Lahaina and Striped Mexican, as before noted, now appear in this tabulation. H 20, H 146, and Yellow Bamboo have been dropped, and McBryde 1 together with H 349 have been added.

Uba cane has increased from .13 per cent in 1927 to .51 per cent this year. Rose Bamboo, Kohala Seedlings, and Wailuku Seedlings have also shown an increase, while Badila, H 456, U. D. 1, and D 117 have declined.

Quality of Cane

Table 2 shows data on the quality of cane for the islands as a group, and for the separate islands for the past ten crops. The quality ratio, or the tons of cane to make a ton of sugar, has improved .2 of a ton since 1927. The quality ratio is still the poorest figure shown the past ten years with the exception of last year.

The quality of cane by islands ranks in the usual order, Maui, the best, followed by Oahu, Kauai and Hawaii.

The polarization of the cane has increased .23, and the first expressed juice purity .56 over 1927. The fiber has remained practically the same in the general average.

Considering the changes in the separate islands it is found that the polarization has increased in each; also that the purity has increased except for Kauai, where there was a slight decline. The quality ratio improved in each instance except that for Kauai, which remained the same. The fiber changes have been small except for a .58 per cent increase on Maui. Maui has always been consistently lower in fiber than the other islands until this year. It is still somewhat below that for Hawaii and Kauai.

Tons cane per acre for 1928 and the three previous years, for the five leading varieties, are shown in the following table. The figures are obtained by combining data from the Acreage Census and the Annual Synopsis. A few discrepancies between the two sets of figures may detract slightly from the strict accuracy of these figures, but they are probably accurate to within one ton per acre.

TABLE NO. 2

COMPOSITION OF CANE BY ISLANDS

	Hawaii	Maui	Oahu	Kauai	Whole Group
1919					
Polarization	12.74	15.12	14.24	13.52	13.74
Per cent Fiber	13.07	11.74	12.14	12.61	12.49
Purity 1st Expressed Juice	87.54	88.81	87.00	85.82	87.34
Quality Ratio	8.66	7.25	7.81	8.20	8.05
1920					
Polarization	12.86	15.29	13.75	13.07	13.64
Per cent Fiber	13.36	11.39	12.65	12.72	12.64
Purity 1st Expressed Juice	87.87	88.94	85.40	86.52	87.24
Quality Ratio	8.45	7.08	8.07	8.28	8.00
1921					
Polarization	12.25	14.67	13.72	12.67	13.12
Per cent Fiber	13.28	11.82	12.40	13.28	12.80
Purity 1st Expressed Juice	87.18	87.37	85.46	84.07	86.22
Quality Ratio	8.98	7.51	8.11	8.76	8.41
1922					
Polarization	12.07	13.95	13.61	13.03	12.97
Per cent Fiber	13.16	12.38	12.88	13.22	12.95
Purity 1st Expressed Juice	87.17	87.88	86.18	85.80	86.84
Quality Ratio	9.19	7.75	8.04	8.36	8.45
1923					
Polarization	12.09	13.61	12.99	12.94	12.78
Per cent Fiber	13.14	12.01	12.86	12.99	12.82
Purity 1st Expressed Juice	87.61	88.65	85.52	86.58	87.05
Quality Ratio	9.12	7.91	8.50	8.42	8.57
1924					
Polarization	12.44	14.34	13.48	13.34	13.26
Per cent Fiber	12.99	12.16	12.72	12.94	12.74
Purity 1st Expressed Juice	87.98	89.19	87.02	87.31	87.86
Quality Ratio	8.86	7.58	8.16	8.12	8.25
1925					
Polarization	12.35	14.42	13.52	13.24	13.22
Per cent Fiber	12.92	12.40	12.60	12.91	12.74
Purity 1st Expressed Juice	88.02	89.36	87.11	87.19	87.92
Quality Ratio	8.92	7.47	8.18	8.21	8.28
1926					
Polarization	12.53	14.66	13.40	13.03	13.24
Per cent Fiber	12.90	12.24	12.72	12.46	12.65
Purity 1st Expressed Juice	87.59	89.03	86.61	86.68	87.45
Quality Ratio	8.80	7.40	8.29	8.39	8.30
1927					
Polarization	11.34	14.00	12.61	12.07	12.32
Per cent Fiber	12.84	11.98	12.29	12.65	12.49
Purity 1st Expressed Juice	86.27	87.85	85.87	85.17	86.28
Quality Ratio	9.81	7.76	8.86	9.19	8.99
1928					
Polarization	11.57	14.13	13.09	12.09	12.55
Per cent Fiber	12.58	12.56	12.13	12.82	12.50
Purity 1st Expressed Juice	86.60	88.76	86.84	85.16	86.84
Quality Ratio	9.62	7.60	8.45	9.19	8.79

TABLE NO. 3

True Averages of All Factories Except Those Using the Petree Process

	1923	1924	1925	1926	1927	1928
Cane—						
Polarization	12.66	13.08	12.99	12.99	12.05	12.30
Fiber	12.91	12.82	12.80	12.71	12.55	12.47
Tons per ton sugar	8.68	8.40	8.45	8.50	9.24	9.03
Bagasse—						
Polarization	1.53	1.52	1.54	1.58	1.50	1.53
Moisture	41.29	41.26	41.25	41.09	41.61	41.36
Fiber	56.48	56.74	56.55	56.64	56.20	56.42
Polarization % cane	0.35	0.34	0.35	0.35	0.33	0.34
Pol. % pol. of cane	2.76	2.63	2.69	2.73	2.77	2.76
Milling loss	2.71	2.68	2.73	2.79	2.66	2.72
Weight % cane	22.84	22.59	22.63	22.44	22.33	22.11
First Expressed Juice—						
Brix	17.99	18.34	18.14	18.24	17.17	17.45
Polarization	15.61	16.07	15.91	15.88	14.74	15.08
Purity	86.77	87.61	87.67	87.05	85.84	86.41
"Java ratio"	81.1	81.4	81.7	81.8	81.7	81.6
Mixed Juice—						
Brix	13.11	13.37	13.44	13.65	12.88	13.04
Polarization	11.00	11.31	11.38	11.48	10.67	10.89
Purity	83.87	84.56	84.67	84.12	82.88	83.47
Weight % cane	111.95	112.66	111.03	110.10	109.71	109.87
Polarization % cane	12.31	12.74	12.64	12.64	11.71	11.96
Extraction	97.24	97.37	97.31	97.27	97.23	97.24
Extraction ratio	0.21	0.21	0.21	0.21	0.22	0.22
Last Expressed Juice—						
Polarization	1.73	1.84	1.90	2.06	1.88	1.94
Purity	68.48	71.73	69.63	68.72	67.76	68.39
Maceration % cane	34.79	35.30	33.66	32.54	32.04	31.99
Syrup—						
Brix	63.33	63.18	63.63	64.21	62.91	63.05
Purity	85.40	86.02	85.95	85.49	84.54	84.86
Increase in purity	1.53	1.46	1.28	1.37	1.66	1.39
Lbs. avail. CaO per ton cane	1.70	1.72	1.56	1.66	1.52	1.46
Press Cake—						
Polarization	2.20	2.16	2.17	2.49	2.22	2.34
Weight % cane	2.45	2.45	2.45	2.63	2.67	2.87
Polarization % cane	0.05	0.05	0.05	0.07	0.06	0.07
Pol. % pol. of cane	0.43	0.40	0.41	0.50	0.49	0.55
Commercial Sugar—						
Polarization	96.88	97.20	97.23	97.29	97.40	97.49
Moisture	0.80	0.73	0.74	0.66	0.64	0.62
Weight % cane	11.53	11.91	11.83	11.77	10.83	11.08
Polarization % cane	11.17	11.58	11.50	11.45	10.55	10.80
Pol. % pol. of cane	88.37	88.76	88.78	88.41	87.96	88.21
Pol. % pol. of juice	90.86	91.16	91.24	90.95	90.45	90.70
Deterioration factor	0.26	0.26	0.27	0.24	0.25	0.25
Final Molasses—						
Weight % cane	2.96	2.83	2.82	2.94	3.02	2.97
Sucrose % cane	0.99	0.97	0.93	0.99	1.01	0.98
Sucrose % pol. of cane	7.79	7.45	7.20	7.63	8.37	8.00
Sucrose % pol. of juice	8.01	7.65	7.40	7.84	8.60	8.22
Gravity solids	88.54	89.08	90.09	89.59	89.43	88.77
Gravity purity	37.68	37.81	36.97	37.62	37.40	37.41
Undetermined Losses—						
Polarization % cane	0.11	0.14	0.16	0.13	0.11	0.11
Pol. % pol. of cane	0.65	0.76	0.92	0.73	0.41	0.48

TONS CANE PER ACRE

	1925	1926	1927	1928
Crop	53.3	54.4	57.5	61.6
H 109	69.4	69.1	73.7	74.5
Yellow Caledonia	44.8	45.0	45.1	52.6
D 1135	49.3	46.4	46.7	55.3
Yellow Tip	41.0	39.8	36.9	42.3
Striped Tip	31.5	37.0	30.6	39.7

All varieties this year show heavier cane yields, not only over 1927, but over the years 1926 and 1925.

Chemical Control

The number of factories reporting sucrose data has been increased by one, so that 31 factories out of 40, representing 87 per cent of the total sugar produced, are now on a sucrose basis.

Table 6, shows gravity solids and sucrose balances for these factories. Sucrose data for the 31 factories are given in Table 7 with true averages for the last three crops.

Final molasses is now weighed at 28 factories, an increase of one. Eight factories measure their molasses for calculating the weight; four neither weigh nor measure molasses.

Mixed juice is weighed at 36 factories, the same number as for several years, while four factories still base their chemical control on juice measurements.

Lime is now reported in pounds available CaO per ton of cane, both in Table 3 and in the large table, thus conforming to the lime figure used in the Weekly Reports.

Data for pH reactions of the hot limed juice, clarified juice and syrup, also for clarified juice turbidity, are given for the second time. Factories reporting at least partial pH reaction data now number 35, as compared with 30 last year. Turbidity is reported from 24, or one more factory than previously. The pH of the heated mixed juice is averaged for the first time. Last year a number of factories reported pH of cold mixed juice, so that a representative average could not be made.

Apparent and true boiling house recoveries are again given in Tables 4 and 5. As noted last year, true sucrose figures in Table 5 should be considered of the greater significance when factories are listed in both tables. The trend toward higher recoveries, maintained for several years, remains unbroken. There are but 3 factories reporting under 97 per cent of available in Table 4, and only 2 in Table 5. There has been an increase of 3 factories reporting 100 per cent or more on available in Table 4, making a total of 26. Ten report over 101 per cent, against 9 last year. In Table 5, 13 factories are over 100 per cent, and 2 over 101 per cent. The decreasing number of factories with low recoveries is in many instances due to better boiling house supervision and control.

The slight discrepancies in our control methods, resulting in the calculated figure for available sucrose being less than the true theoretical figure for available, have been discussed at length in previous Synopses. While these discrepancies can account for recoveries on available slightly in excess of 100 per cent, it would seem that figures in Table 5, higher than 101 per cent, indicate errors in the con-

TABLE NO. 4

APPARENT BOILING-HOUSE RECOVERY

Comparing per cent available sucrose in the syrup (calculated by formula) with per cent polarization actually obtained.

Factory	Available*	Obtained	Recovery on Available	Molasses Produced on Theoretical†
H. C. & S. Co	93.27	94.76	101.6	88.7
Oahu	91.75	93.27	101.7	76.8
Ewa	91.87	92.29	100.5	85.9
Waialua	90.90	90.73	99.8	85.7
Maui Agr.	93.23	94.39	101.2	100.5
Pioneer	91.93	92.65	100.8	90.0
Olaa	91.19	89.65	98.3	97.6
Haw. Sug	92.95	93.98	101.1	91.1
Lihue	89.61	90.80	101.3	78.0
Honolulu	90.80	87.43	96.3	95.8
Onomea	91.42	91.88	100.5	89.6
Hilo	91.37	92.38	101.1	86.7
Kekaha	90.11	90.12	100.0	91.2
Haw. Agr.	90.42	90.34	99.9	90.3
Wailuku	91.90	92.41	100.6	95.2
Hakalau	91.67	92.59	101.0	89.2
Makee	86.71	87.86	101.3	83.7
Honokaa	89.06	89.89	100.9	91.7
McBryde	91.94	92.54	100.7	88.2
Laupahoehoe	93.72	93.01	99.2	84.4
Kahuku	89.95	93.02	103.4	92.3
Hamakua	92.27	92.82	100.6	81.5
Pepeekeo	92.26	93.05	100.9	88.1
Paauhau	90.05	89.54	99.4	92.7
Koloa	89.22	90.61	101.6	92.7
Honomu	92.08	92.67	100.6	93.4
Waiakea	89.32	87.80	98.3	86.3
Hawi	88.09	87.52	99.4	91.0
Hutchinson	90.67	90.14	99.4	92.9
Kaiwiki	90.61	90.90	100.3	92.0
Waimanalo	90.30	90.45	100.2	89.2
Kohala	91.14	91.52	100.4	91.4
Kilauea	84.07	83.79	99.7	86.2
Waianae	90.16	88.21	97.8	87.1
Kaeleku	86.54	85.86	99.2	81.7
Union Mill	89.61	90.15	100.6	....
Halawa	89.90	90.33	100.5	....
Niulii	86.13	88.38	102.6	....
Waimea	91.23	85.67	93.9	....
Olowalu	89.62	81.77	91.2	71.6

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When moisture in sugar has not been reported, the moisture corresponding to 0.25 deterioration factor has been used. 38 has been used when the gravity purity of the molasses has not been reported.

† Gravity solids in syrup, less solids accounted for in commercial sugar considered as theoretical gravity solids in final molasses.

TABLE NO. 5

TRUE BOILING-HOUSE RECOVERY

Comparing per cent sucrose available and recovered

Factory	Available	Obtained	% Recovery on Available	Molasses Produced on Theoretical*
H. C. & S. Co.	93.27	94.27	101.1	83.7
Oahu	91.88	92.34	100.5	73.6
Ewa	91.94	91.58	99.6	86.6
Waialua	90.97	89.33	98.2	87.7
Maui Agr.	93.46	93.64	100.2	100.7
Pioneer	92.00	91.78	99.8	89.8
Haw. Sug.	93.02	93.08	100.1	88.7
Lihue	89.94	89.43	99.4	77.9
Honolulu	91.05	86.28	94.8	113.9
Onomea	91.46	91.55	100.1	90.3
Hilo	91.13	92.04	101.0	82.6
Haw. Agr.	90.63	89.44	98.7	96.7
Wailuku	92.01	91.68	99.6	95.9
Hakalau	91.82	91.89	100.1	89.1
Makee	86.86	86.70	99.8	82.3
Honokaa	89.06	89.32	100.3	90.4
McBryde	92.06	91.68	99.6	89.0
Laupahoehoe	93.53	92.57	99.0	87.6
Kahuku	90.13	91.63	101.7	84.9
Hamakua	92.25	92.38	100.1	82.6
Pepeekeo	92.51	92.77	100.3	90.1
Paauhau	90.00	89.01	98.9	95.6
Koloa	89.39	89.63	100.3	91.0
Honomu	92.10	92.16	100.1	92.0
Waiakea	89.63	87.04	97.1	95.4
Hutchinson	90.61	89.72	99.0	96.3
Waimanalo	90.19	89.94	99.7	88.1
Kohala	91.37	91.05	99.7	94.0
Kilauea	84.30	82.82	98.2	87.0
Waianae	90.26	87.66	97.1	94.4
Olowalu	89.28	81.46	91.2	90.2

* Calculated by the S. J. M. formula.

TABLE NO. 6
GRAVITY SOLIDS AND SUCROSE BALANCES

Factory	Gravity Solids per 100 Gravity Solids in Mixed Juice				Sucrose per 100 Sucrose in Mixed Juice			
	Press Cake	Commercial Sugar	Final Molasses	Undetermined	Press Cake	Commercial Sugar	Final Molasses	Undetermined
H. C. & S. Co.	...	85.2	13.1	1.7	...	94.27	5.63	0.10
Oahu	6.0	76.9	13.0	4.1	0.85	91.56	5.97	1.62
Ewa	5.7	75.3	16.3	2.7	0.54	91.09	6.98	1.39
Waialua	4.3	75.0	17.0	3.7	0.47	88.91	7.92	2.70
Maui Agr.	...	84.1	16.0	—0.1	...	93.64	6.58	—0.22
Pioneer	4.4	76.7	16.9	2.0	0.32	91.49	7.18	1.01
Haw. Sug	4.3	79.8	14.3	1.6	0.76	92.37	6.19	0.68
Lihue	4.3	72.6	17.8	5.3	0.51	88.97	7.84	2.68
Honolulu	4.3	72.5	22.0	1.2	0.52	85.83	10.19	3.46
Onomea	4.4	75.8	18.0	1.8	0.14	91.42	7.72	0.72
Hilo	5.2	76.7	15.7	2.4	0.41	91.66	7.32	0.61
Haw. Agr.	3.4	75.7	18.8	2.1	0.41	89.07	8.82	1.70
Wailuku	4.7	78.0	16.4	0.9	0.44	91.28	7.65	0.63
Hakalau	3.7	77.0	17.3	2.0	0.15	91.75	7.28	0.82
Makee	4.1	69.0	22.1	4.8	0.44	86.32	10.81	2.43
Honokaa	6.3	70.9	20.9	1.9	0.64	88.75	9.89	0.72
McBryde	3.3	77.4	16.9	2.4	0.41	91.30	7.06	1.23
Laupahoehoe	4.1	79.4	13.8	2.7	0.17	92.41	5.66	1.76
Kahuku	6.0	72.5	19.4	2.1	0.81	90.89	8.37	—0.07
Hamakua	...	81.1	15.4	3.5	...	92.38	6.40	1.22
Pepeekeo	5.3	76.8	16.4	1.5	0.17	92.61	6.76	0.46
Paauhau	4.5	74.3	19.6	1.6	0.47	88.59	9.56	1.38
Koloa	5.8	70.6	21.7	1.9	0.55	89.14	9.66	0.65
Honomu	5.2	76.9	16.6	1.3	0.20	91.98	7.27	0.55
Waiakea	6.0	72.1	19.0	2.9	0.98	86.19	9.89	2.94
Hutchinson	7.3	72.2	19.1	1.4	0.43	89.33	9.04	1.20
Waimanalo	5.5	73.5	18.4	2.6	0.39	89.59	8.64	1.38
Kohala	5.3	76.1	17.4	1.2	0.86	90.27	8.11	0.76
Kilauea	4.0	63.1	28.0	4.9	1.41	81.65	13.66	3.28
Waianae	4.5	72.4	20.0	3.1	1.01	86.77	9.19	3.03
Olowalu	5.7	65.4	20.5	8.4	0.30	81.22	9.67	8.81

TABLE NO. 7
SUCROSE DATA

Factory	Cane Sucrose*	MIXED JUICE Sucrose	MIXED JUICE Gravity Purity	SYRUP Gravity Purity	SYRUP Increase in Purity	SUGAR Sucrose	SUGAR Sucrose per 100 Sucrose* in cane	Undetermined Loss per 100 Sucrose* in cane
H. C. & S. Co.	15.02	12.95	89.06†	89.07	0.01	97.98	91.78	0.10
Oahu	13.50	12.07	86.46	87.57	1.11	98.37	89.68	1.59
Ewa	13.10	11.14	84.08	86.00	1.92	98.12	89.32	1.37
Waialua	13.64	11.61	85.65	86.5	0.85	97.99	86.46	2.62
Maui Agr.	14.28	12.52	88.36†	88.53	0.17	97.79	91.30	—0.21
Pioneer	14.08	12.87	85.01	86.06	1.05	98.01	89.04	0.98
Haw. Sug.	14.39	13.13	87.36	88.43	1.07	98.18	90.10	0.67
Lihue	11.68	10.56	82.44	83.3	0.86	97.50	86.78	2.61
Honolulu	13.69	11.81	86.71	87.8	1.09	100.00	83.15	3.36
Onomea	11.07	9.55	84.14	85.26	1.12	97.77	90.13	0.71
Hilo	11.48	10.06	85.47	86.49	1.02	97.69	89.87	0.59
Haw. Agr.	11.78	11.44	85.37	86.32	0.95	97.95	86.71	1.66
Wailuku	13.60	11.00	86.75	87.9	1.15	97.78	89.68	0.63
Hakalau	11.39	9.74	84.70	85.47	0.77	97.33	90.53	0.81
Makee	11.05	9.97	81.32	81.7	0.38	97.46	82.13	2.31
Honokaa	10.07	9.39	82.01	83.53	1.52	98.08	84.58	0.69
McBryde	12.92	11.06	85.27	85.79	0.52	97.68	88.29	1.19
Laupahoehoe	12.29	10.34	86.90	88.12	1.22	97.72	89.71	1.71
Kahuku	11.55	9.87	81.63	82.84	1.21	97.90	88.73	—0.07
Hamakua	12.29	12.24	86.13†	86.45	0.32	97.47	89.83	1.18
Pepeekeo	11.97	11.01	84.04	86.20	2.16	98.18	90.45	0.45
Paauhau	11.28	9.64	84.34	85.55	1.21	97.23	86.39	1.35
Koloa	10.88	9.75	80.58	82.4	1.82	97.92	86.37	0.63
Honomu	12.04	10.14	84.57	86.8	2.23	98.21	90.29	0.53
Waiakea	11.90	11.72	84.32	86.48	2.16	97.28	82.45	2.81
Hutchinson	12.18	11.90	83.98	85.11	1.13	97.42	86.52	1.16
Waimanalo	11.92	9.91	82.52	84.72	2.20	97.25	88.46	1.31
Kohala	12.25	9.78	85.04	86.68	1.64	97.43	87.89	0.74
Kilauea	9.96	9.28	77.99	77.96	—0.03	97.41	78.62	3.16
Waianae	14.05	11.75	83.75	84.87	1.12	97.30	84.21	2.89
Olowalu	13.57	11.32	81.81	83.26	1.45	96.95	79.24	8.60
‡True Average 1928	12.69	11.22	85.15	86.23	1.08	97.86	88.49	1.21
" " 1927	12.46	11.01	84.53	85.86	1.33	97.79	87.96	1.13
" " 1926	13.35	11.68	85.38	86.66	1.28	97.67	88.41	1.20

* Polarization in bagasse and press cake has been assumed to be the same as sucrose in calculating sucrose in cane.
† Clarified juice.

trol, and that there is the same indication in Table 4, though not to such a positive degree.

Molasses produced on the theoretical is shown in both Tables 4 and 5. The calculation in Table 4 is based on the theoretical being the difference between the gravity solids in the syrup and in the sugar produced. In Table 5, the S. J. M. formula is used. There should be comparatively little difference in the two sets of figures, if there are no discrepancies in the control data, hence their value in checking the control.

It is quite obvious that the factors which depress the calculated available sucrose, increase the figure for the calculated theoretical molasses to a considerably greater extent. The average molasses produced on theoretical in Table 4 for the past six crops has fluctuated between a minimum of 88.6, this year's figure, and a maximum of 91.2 in 1927. The six crops' average is 90.2. While conditions at certain factories may cause more or less variation from the theoretical, a difference of over 5 on either side of the six-year average would indicate, for the factories that are high, errors in control, and for those that are low, control errors, undetermined loss of solids, or both. There are 3 factories over this limit and 7 below.

Table 6 shows gravity solids and sucrose balances for the 31 factories reporting available data. One factory has a negative undetermined loss of solids, and two factories report a negative undetermined loss of sucrose. Both these items indicate error in chemical control. Of the eight factories showing a negative undetermined loss on a polarization basis in the first large table, only the two factories noted above with negative undetermined sucrose have a negative undetermined polarization above one per cent.

Milling

Changes in milling machinery since last year include knives and a new three-roller crusher at Hutchinson factory in place of an old two-roller crusher, and knives at Hawaiian Agricultural Company. A good increase in extraction for both factories is reported. Makee temporarily dispensed with their shredder during the crop just harvested, but this will be restored to use the coming year.

Below is given data pertinent to milling for the past eight seasons:

Year	Tons cane per hour	Tonnage ratio	Tonnage fiber ratio	Tons pressure per linear ft. roller	Maceration per cent cane	Milling loss	Extraction ratio	Extraction
1921	36.58	1.40	17.9	....	39.30	2.64	.20	97.43
1922	39.93	1.54	19.9	65.2	34.75	3.02	.23	96.98
1923	42.03	1.56	20.0	66.2	35.12	2.76	.22	97.23
1924	43.63	1.62	20.6	66.9	34.90	2.78	.21	97.33
1925	45.31	1.71	21.8	66.5	33.63	2.82	.21	97.29
1926	46.43	1.78	22.5	67.4	33.61	2.88	.22	97.25
1927	47.87	1.78	22.2	68.2	32.53	2.73	.22	97.23
1928	49.30	1.83	22.9	70.5	32.16	2.75	.21	97.26

It will be noted that the trend toward increased rate per hour, tonnage ratio and tonnage fiber ratio has remained unbroken, except for a temporary hesitancy in the tonnage ratio and a slight reversal in tonnage fiber ratio last year. The roller pressures have increased each year except in 1925. The maceration percentage has been distinctly downward for the past ten years. Fiber in cane, though not shown above, has had a downward tendency since reaching the high figure of 12.95 in 1922.

Milling efficiency, as evidenced by milling loss, extraction ratio, and extraction, gained rapidly during the years prior to those shown in the above table. These figures reached their peak for all time in 1920 and 1921, with 2.64 milling loss in 1921, .20 extraction ratio in 1920 and 1921, and 97.45 extraction in 1920. Since then the fluctuations shown above have occurred. Higher grinding rates and lower maceration, notwithstanding increased pressures, have decreased milling efficiency about .1 in milling loss, .01 in extraction ratio, and .2 in extraction.

The average maceration this year is 32.16, the lowest figure for sixteen years. All factories reporting 98 extraction or over, 7 in number, show approximately 35 to 40 per cent maceration. In many factories lower maceration has been necessary because of their increased grinding rate with no accompanying increase in evaporative capacity. The question arises as to how much lower maceration can be reduced without having a marked effect on milling results. We know that the present efficiency of maceration is low, and that it is a promising field for study and improvement. There is some evidence that improvements of a practical nature are being developed.

In comparing this year's milling results with those of last year, it is found that there has been a small improvement in extraction and extraction ratio accompanied by a 3 per cent increase in grinding rate with a like increase in tonnage fiber ratio. The milling loss is slightly poorer, and maceration per cent cane has decreased. Bagasse moisture is .30 lower, and the polarization .02 higher. Twenty-four factories report increased extraction with 15 reporting a decrease and one with no change.

Data for non-Petree process factories show a slight reduction in the difference between first expressed juice purity and mixed juice purity, 2.94 against 2.96. Any reduction is a hopeful sign of either cleaner mill conditions, less cane trash, or both.

Table 8 shows the factories listed in the order of their milling loss, with other milling data in the same form as the past two years. Hakalau and Onomea have been passed by Waimanalo. Hilo and Honomu retain their same relative positions. Hawi has jumped from 21st to 6th position. In 1926 this factory was number 32 in the list. The factories that have also materially bettered their positions are Hutchinson, Maui Agricultural Co., Hawaiian Agricultural Co. and Kohala, in the order named. Those that show a position considerably lower than last year are Waialua, Pioneer, Kekaha, Honolulu, McBryde and Waimea.

TABLE NO. 8—MILLING RESULTS

Showing the Rank of the Factories on the Basis of Milling Loss.

Rank	1927 Rank	Factory	Milling Loss	Extraction Ratio	Extraction	Maceration	Tonnage Ratio	Tonnage Fiber Ratio*
1	3	Waimanalo....	1.16	0.10	98.67	40.18	1.97	26.44
2	1	Hakalau.......	1.23	0.11	98.65	36.09	1.74	21.40
3	2	Onomea.......	1.29	0.12	98.57	34.97	1.96	23.85
4	4	Hilo..........	1.65	0.14	98.03	34.98	1.81	24.65
5	5	Honomu.......	1.82	0.15	98.15	37.57	1.51	18.32
6	21	Hawi.........	2.02	0.16	97.84	32.71	1.72	22.69
7	8	Wailuku.......	2.03	0.15	98.23	40.91	1.27	14.87
8	11	Paauhau.......	2.14	0.19	97.50	36.50	1.10	14.37
9	6	Kahuku.......	2.16	0.19	97.58	35.82	1.57	20.10
10	7	Ewa..........	2.17	0.17	98.04	36.68	1.76	20.63
11	14	Lihue.........	2.18	0.19	97.49	31.79	2.19	28.78
12	12	Pepeekeo......	2.23	0.19	97.66	27.22	1.85	23.05
13	15	Oahu..........	2.26	0.17	97.92	31.20	1.91	23.47
14	10	Olowalu.......	2.41	0.18	97.55	39.21	1.55	21.05
15	9	Kekaha.......	2.42	0.19	97.87	27.55	1.85	21.22
16	13	Hamakua......	2.57	0.22	97.20	21.39	1.40	18.63
17	19	Koloa.........	2.59	0.24	96.85	30.67	1.42	18.55
18	27	Haw. Agr.....	2.67	0.23	97.32	20.33	1.96	22.87
19	24	Kohala........	2.73	0.23	97.34	42.40	1.63	19.10
20	17	Kilauea.......	2.77	0.28	96.24	27.33	1.53	20.38
21	22	Haw. Sug.....	2.78	0.20	97.52	28.96	1.63	20.72
22	32	Maui Agr.....	2.84	0.20	97.48	34.13	2.00	25.00
23	20	Laupahoehoe..	2.85	0.23	97.05	36.95	1.68	21.17
24	37	Hutchinson....	3.01	0.25	96.83	21.12	1.96	25.03
25	18	Pioneer.......	3.02	0.22	97.28	30.51	2.20	27.50
26	28	H. C. & S. Co..	3.11	0.21	97.35	35.75	1.82	23.11
27	16	Waialua.......	3.17	0.24	96.96	37.71	2.50	32.00
28	23	McBryde......	3.19	0.25	96.68	36.62	1.42	18.94
29	26	Olaa..........	3.25	0.27	96.83	29.23	2.33	27.61
30	25	Waimea.......	3.31	0.25	96.91	38.00	1.48	18.34
31	30	Waianae.......	3.65	0.26	96.97	36.42	1.53	17.64
32	35	Waiakea.......	3.74	0.32	95.61	22.68	1.60	22.06
33	31	Honokaa......	3.74	0.38	95.26	26.11	1.66	20.93
34	29	Honolulu......	3.90	0.29	96.84	32.02	1.82	19.89
35	34	Kaiwiki.......	3.91	0.31	96.16	31.77	1.71	20.95
36	33	Makee........	4.06	0.37	95.06	29.55	2.17	28.75
37	36	Kaeleku.......	4.07	0.36	94.91	30.48	1.89	26.67
38	38	Niulii.........	4.39	0.42	94.24	26.73	1.88	25.79
39	40	Halawa.......	5.12	0.44	93.82	28.76	1.67	23.33
40	39	Union Mill....	5.56	0.48	93.50	22.91	1.72	23.19

* Tonnage ratio multiplied by per cent fiber in cane.

Boiling House Work

Clarification: The averages in Table 3, for non-Petree process factories show that the increase in purity from mixed juice to syrup is .27 less than last year. This is influenced slightly by the higher purity of the first expressed juice this year. Twenty-three factories report a smaller increase, 16 a larger figure, and 1 no change. The purity increase figure now stands at 1.39, and in the light of clarification investigations carried on for several years by this Station, it appears far lower than that obtainable when the mixed juice is limed to the point recommended for the best increase. The importance of purity increase is apparent when it is realized that there is additional recovery that is practically equal to the purity increase. We have this year pH figures for limed mixed juice from 28 factories, and 18 show reactions below the range that experimental work has indicated the maximum increase in purity is secured. There are 6 factories not reporting any pH data, and the average purity increase is only .91 for these factories, compared with 1.39 for all non-Petree factories.

The figure for lime per ton of cane is less than last year, indicating, though not positively, that the juice has been limed on the whole to a lower reaction.

Liming at a number of factories is carried at a moderate reaction because of inadequate filter press equipment. The volume of settlings is reduced by reducing the amount of lime used in clarification, and with the increased rate of grinding without additional increase in filtration equipment, the situation becomes more acute.

The turbidity of clarified juice as reported by the 24 factories that are regularly making these tests is 3.46 this year, compared with 3.59 last year. As the individual factories reporting turbidity for the two years are practically identical, the two figures are comparable, thus showing a more turbid juice this year for these factories. Several factories are becoming decidedly under capacity in settling equipment. Experimental work has shown that underliming produces less clear juices. The work has also shown that poor clarification is one of the factors affecting the filtration rate of sugars.

The smaller increase of purity in clarification has shown its influence on the difference between first expressed juice and syrup, this having increased .17 this year. The figures for the last seven crops are tabulated below:

Year	Purity difference first expressed juice to syrup
1922	1.88
1923	1.40
1924	1.54
1925	1.65
1926	1.67
1927	1.41
1928	1.58

Filter Presses: As shown by data in Table 3, it is found that the filter press work is less satisfactory than last year. The cake polarization has increased from 2.22 to 2.34, the amount of cake per cent cane from 2.67 to 2.87, and the loss per cent polarization of cane from .49 to .55. The weight and loss are the largest crop figures that have been reported.

As a result of faster grinding a number of factories allowed more cush-cush to pass into the mixed juice to improve the filtration characteristics of the settlings, thus increasing filter capacity. Faster grinding can account for the larger loss.

The Oliver filtration equipment at Oahu has been increased the past year, though not to the point that these filters have handled all the settlings. One Oliver unit was in use this year at Olaa. These filters are giving satisfactory service.

Evaporation: With faster grinding and very little, if any, change in evaporator equipment, the syrup has dropped but little in density this year. The syrup density was at its highest figure on record, 64.04 Brix in 1926. In 1927, there was a drop to 63.10; this year it is 63.04. The equipment is being operated at higher capacity each year. The percentage increase of evaporation per hour from year to year is as follows: 1925, 2.6; 1926, 2.6; 1927, 3.2; and 2.3 per cent in 1928.

Commercial Sugar: The polarization of sugar has increased .11, or to 97.51. The only previous year that this figure has been exceeded was 97.55 in 1911. After 1911 there was a decline in polarization to a low figure of 96.3 in 1916. In 1919 the polarization was 96.34, since which time there has been a yearly increase to the present average of 97.51.

The average increase in polarization this year is again brought about by an increase in polarization by the group of factories shipping to the Crockett refinery. There has been a further decline in the average polarization of Western refinery factories. The polarization spread between the two factory groups is .79, the averages being 97.70 for Crockett and 96.91 for Western.

The moisture in sugar is again somewhat lower than the previous year, .62 as compared with .65. The deterioration factor is down to a new low figure, .249. While the average is below the limit of .250 recommended for safety from deterioration, it means that there is still a large proportion of the sugar above this figure subject to polarization loss if the sugar is stored for any extended length of time.

The grain of the sugar has been better this year than for several years. Seventy-two per cent of the factories reduced the amount of small grain. The average filtration rate of the sugar shipped to Crockett refinery up to the end of October, had increased 1.8, or to 80.9. The maximum rate was 81.5 in 1926.

The amount of sour sugar is less than previously reported for any crop, though the amount of hard sugar has increased. The quality of commercial sugar is further discussed in the Raw Sugar Technical Committee Report.

Low Grades: The gravity purity of final molasses is again lower than that for the previous year, standing at 37.39 as compared with 37.59 for 1927, and 37.97 in 1926. The record low purity was 37.32 in 1925. Twenty-one factories report lower gravity purity than last year, and 16 show a higher figure. No factory has equalled the low record purity of 31.81 made by Kahuku last year. Two factories, Laupahoehoe and Waianae, have installed crystallizers in place of cooling tanks. The decreases in molasses gravity purity from the year before were 6.87 and 5.70 respectively. Hamakua and Hutchinson have had crystallizers for two crops, or slightly less, and their decreased purity since two years ago is 6.98

TABLE NO. 9

COMPARISON OF ACTUAL AND THEORETICAL RECOVERIES

Recovery % Calculated Recovery *					Recovery % Recovery Indicated by "Sugar Ratio" †	
Rank	Factory	Milling	Boiling House	Over All	Rank	Over All
—	Kahuku	97.58	104.62	102.49	—	101.10
1	Hakalau	98.65	102.02	100.87	1	100.59
2	Onomea	98.57	101.44	100.27	2	100.30
3	Pepeekeo	97.66	102.22	99.98	3	99.89
—	Lihue	97.49	101.99	99.93	—	99.10
—	Koloa	96.85	102.62	99.85	—	98.92
—	Maui Agr	97.48	101.61	99.48	—	99.71
4	Honomu	98.15	100.97	99.39	4	99.39
5	Ewa	98.04	100.95	99.28	5	99.28
—	H. C. & S. Co	97.35	101.38	99.06	—	99.53
6	Pioneer	97.28	101.43	99.03	7	98.60
7	Hamakua	97.20	101.25	98.86	11	97.79
—	Oahu	97.92	100.49	98.68	—	99.32
—	Hilo	98.03	100.28	98.58	—	99.18
8	Waimanalo	98.67	99.62	98.54	6	98.73
9	McBryde	96.68	101.38	98.30	8	98.27
—	Haw. Sug	97.52	100.51	98.22	—	98.72
10	Wailuku	98.23	99.45	97.95	12	97.43
11	Kekaha	97.87	99.52	97.93	9	97.80
12	Laupahoehoe	97.05	99.88	97.22	9	97.80
13	Kohala	97.34	99.09	96.76	13	97.41
14	Haw. Agr	97.32	98.71	96.27	14	96.59
15	Waialua	96.96	98.85	96.25	16	96.39
16	Hawi	97.84	97.92	96.19	18	95.48
17	Hutchinson	96.83	98.99	96.16	17	95.99
18	Honokaa	95.26	100.45	96.12	19	95.32
—	Makee	95.06	100.22	95.89	—	93.20
19	Paauhau	97.50	97.83	95.69	15	96.40
20	Kilauea	96.24	98.65	95.57	22	93.68
21	Kaiwiki	96.16	98.23	94.77	20	95.14
22	Waianae	96.97	96.74	94.13	23	93.45
23	Olaa	96.83	96.85	94.06	21	94.48
—	Niulii	94.24	98.53	93.39	—	91.76
24	Halawa	93.82	98.24	92.59	25	93.22
25	Honolulu	96.84	95.13	92.45	24	93.39
26	Kaeleku	94.91	96.55	92.06	28	91.13
27	Waiakea	95.61	95.07	91.23	27	91.32
28	Union Mill	93.50	97.06	91.13	26	91.59
29	Waimea	96.91	93.29	90.64	29	90.89
30	Olowalu	97.55	91.17	89.31	30	87.56

* Factories are arranged in the order of the ratio of their recovery to that calculated on the basis of 100% extraction, 37.5 gravity purity molasses and no other losses. Factories reporting boiling house recovery in excess of 101% on available (Table 4) are included in the table but no ranking is assigned.

† The basis of this calculation is 98.02 extraction, syrup purity one less than the apparent purity of the first expressed juice, gravity purity of molasses 33.33 and no other losses. In this case also no rank has been assigned when over 101% boiling house recovery on available has been reported.

and 3.65 respectively. Other factories that show a marked decrease in molasses purity this year are McBryde, H. C. & S. Co., Maui Agricultural Co., and Kaeleku. There are five factories at which the gravity purity of the molasses has increased 1.0 or more since 1927.

Undetermined Loss: The undetermined polarization loss as shown on the large table remains at .32, the same as in 1927. For the 31 factories on a sucrose basis the loss has increased .08 to 1.21, or about the same as for 1926. At many of the factories these loss figures fluctuate widely from year to year, so that it is hard to draw conclusions from small changes in the averages. It can be said, however, that since higher liming went into practice in 1922 and 1923, there has been more than 1 per cent reduction in the undetermined loss.

Recovery

Boiling house recovery has increased from 90.76 to 91.24, and recovery per cent polarization in cane from 88.25 to 88.76, or .48 and .50 respectively.

Factors tending toward higher recovery this year are, higher extraction, higher initial purities, lower purity final molasses, and the smaller decrease in purity from first expressed to mixed juice. Those that tend toward lower recovery are, the smaller purity increase in clarification, larger press loss, and higher sugar polarization. The higher polarization tends to decrease the recovery .05. As higher sugar polarization does not decrease the recovery of available sugar it can be considered that the recovery has increased .55. Calculations based on normal juice indicate that with the better initial purity the recovery should have increased .58. To this would be added .03 for better extraction, and .10 for lower molasses purity. However, the poorer work in clarification, and higher filter press loss decrease the figure .21 and .05 respectively. We thus have a net indicated gain over last year of .45, compared with an actual gain of .55, reflecting slightly better boiling house efficiency.

The 1928 year's results show that we have had a better quality cane, have slightly increased mill extraction, and improved in our low grade work. Our undetermined losses are low. The results in clarification and filter press work are somewhat poorer, but this can be attributed to the increased grinding rate, with very little provision made toward strengthening these stations in the factories that are distinctly under capacity.

Comparison of Actual and Calculated Recoveries

Table 9 shows the comparisons and ranking of the factories in the same form as last year. Factories with over 101 per cent of the theoretical boiling house recovery in Table 4 are included but not given a ranking number. Several factories have materially bettered their standing.

As expressed in previous Synopses, these calculations are of value in obtaining an approximate idea of the quality of the work in the various factories, but drawing close distinctions is not justified. If very close comparisons are to be made they would have to be based on an analysis of all available control data.

The summary of losses is given in the usual form in Table 10.

The calculations in this Synopsis have been made by A. Brodie with the assistance of others in this department.

TABLE NO. 10

SUMMARY OF LOSSES

FACTORY	Pounds Polarization per Ton of Cane: Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Polarization per 100 Cane: Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Polarization per 100 Polarization of Cane: Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Syrup Purity	FACTORY
H. C. & S. Co.	8.00	...	16.40	...	—1.20	23.20	0.40	...	0.82	...	—0.06	1.16	2.65	...	5.53	...	—0.42	7.76	88.33	H. C. & S. Co.
Oahu	5.60	2.20	15.80	1.80	—0.20	25.20	0.28	0.11	0.79	0.09	—0.01	1.26	2.08	0.84	5.92	0.67	—0.05	9.46	86.67	Oahu
Ewa	5.00	1.40	18.00	...	1.60	26.00	0.25	0.07	0.90	...	0.08	1.30	1.96	0.54	6.93	...	0.59	10.02	85.03	Ewa
Waialua	8.20	1.20	21.00	...	3.00	33.40	0.41	0.06	1.05	...	0.15	1.67	3.04	0.46	7.83	...	1.12	12.45	85.6	Waialua
Maui Agr.	7.20	...	18.20	...	—2.80	22.60	0.36	...	0.91	...	—0.14	1.13	2.52	...	6.49	...	—1.02	7.99	87.41	Maui Agr.
Pioneer	7.60	0.80	19.80	...	0.20	28.40	0.38	0.04	0.99	...	0.01	1.42	2.72	0.32	7.07	...	0.06	10.17	85.20	Pioneer
Olaa	7.80	1.80	22.00	...	2.20	33.80	0.39	0.09	1.10	...	0.11	1.69	3.17	0.72	9.00	...	0.94	13.83	86.1	Olaa
Haw. Sug.	7.00	2.20	17.40	...	—0.80	25.80	0.35	0.11	0.87	...	—0.04	1.29	2.48	0.75	6.11	...	—0.28	9.06	87.59	Haw. Sug.
Lihue	5.80	1.20	17.80	...	2.60	27.40	0.29	0.06	0.89	...	0.13	1.37	2.51	0.51	7.79	...	1.13	11.94	82.0	Lihue
Honolulu	8.60	1.40	27.00	...	....	....	0.43	0.07	1.35	...	....	...	3.16	0.51	10.00	...	....	....	86.7	Honolulu
Onomea	3.20	0.20	16.80	...	0.80	21.00	0.16	0.01	0.84	...	0.04	1.05	1.43	0.13	7.66	...	0.33	9.55	84.39	Onomea
Hilo	4.40	1.00	16.40	...	0.40	22.20	0.22	0.05	0.82	...	0.02	1.11	1.97	0.40	7.24	...	0.20	9.81	85.93	Hilo
Kekaha	5.60	1.40	23.60	...	1.40	32.00	0.28	0.07	1.18	...	0.07	1.60	2.13	0.52	9.06	...	0.56	12.27	84.09	Kekaha
Haw. Agr.	6.20	1.00	20.20	...	1.60	29.00	0.31	0.05	1.01	...	0.08	1.45	2.68	0.41	8.68	...	0.68	12.45	85.34	Haw. Agr.
Wailuku	4.80	1.20	20.40	...	—0.60	25.80	0.24	0.06	1.02	...	—0.03	1.29	1.77	0.43	7.62	...	—0.19	9.63	86.8	Wailuku
Hakalau	3.00	0.40	16.40	...	....	19.80	0.15	0.02	0.82	...	....	0.99	1.35	0.15	7.30	...	....	8.80	84.19	Hakalau
Makee	10.80	0.80	22.80	...	2.20	36.60	0.54	0.04	1.14	...	0.11	1.83	4.94	0.42	10.45	...	1.04	16.85	80.7	Makee
Honokaa	9.40	1.20	19.00	...	0.20	29.80	0.47	0.06	0.95	...	0.01	1.49	4.74	0.62	9.51	...	0.06	14.93	82.70	Honokaa
McBryde	8.40	1.00	17.60	...	0.80	27.80	0.42	0.05	0.88	...	0.04	1.39	3.32	0.41	6.91	...	0.28	10.92	84.86	McBryde
Laupahoehoe	7.20	0.40	13.40	...	3.00	24.00	0.36	0.02	0.67	...	0.15	1.20	2.95	0.17	5.55	...	1.23	9.90	87.46	Laupahoehoe
Kahuku	5.40	1.80	18.80	...	—3.60	22.40	0.27	0.09	0.94	...	—0.18	1.12	2.42	0.80	8.31	...	—1.55	9.98	81.89	Kahuku
Hamakua	6.80	...	15.40	...	1.80	24.00	0.34	...	0.77	...	0.09	1.20	2.80	...	6.27	...	0.71	9.78	85.67	Hamakua
Pepeekeo	5.60	0.40	15.80	...	0.20	22.00	0.28	0.02	0.79	...	0.01	1.10	2.34	0.17	6.66	...	0.12	9.29	84.89	Pepeekeo
Paauhau	5.60	1.00	21.00	...	1.60	29.20	0.28	0.05	1.05	...	0.08	1.46	2.50	0.47	9.43	...	0.71	13.11	84.57	Paauhau
Koloa	6.80	1.20	20.40	...	—1.00	27.40	0.34	0.06	1.02	...	—0.05	1.37	3.15	0.55	9.47	...	—0.44	12.73	81.4	Koloa
Honomu	4.40	0.40	17.20	...	....	22.00	0.22	0.02	0.86	...	....	1.10	1.85	0.20	7.20	...	—0.02	9.23	86.0	Honomu
Waiakea	10.40	2.20	22.60	...	4.60	39.80	0.52	0.11	1.13	...	0.23	1.99	4.39	0.95	9.56	...	1.98	16.88	85.39	Waiakea
Hawi	5.40	0.60	27.20	...	2.60	35.80	0.27	0.03	1.36	...	0.13	1.79	2.16	0.24	11.10	...	1.08	14.58	82.53	Hawi
Hutchinson	7.60	1.00	21.40	...	1.60	31.60	0.38	0.05	1.07	...	0.08	1.58	3.17	0.42	8.83	...	0.67	13.09	84.32	Hutchinson
Kaiwiki	9.60	2.20	21.00	...	0.60	33.40	0.48	0.11	1.05	...	0.03	1.67	3.84	0.87	8.40	...	0.27	13.38	85.72	Kaiwiki
Waimanalo	3.20	0.80	20.40	...	1.80	26.20	0.16	0.04	1.02	...	0.09	1.31	1.33	0.38	8.62	...	0.77	11.10	'3.92	Waimanalo
Kohala	6.40	2.00	19.40	...	0.60	28.40	0.32	0.10	0.97	...	0.03	1.42	2.66	0.84	7.97	...	0.22	11.69	85.5	Kohala
Kilauea	7.40	2.60	26.20	...	4.00	40.20	0.37	0.13	1.31	...	0.20	2.01	3.76	1.37	13.35	...	2.04	20.52	76.9	Kilauea
Waianae	8.40	2.80	25.00	...	6.40	42.60	0.42	0.14	1.25	...	0.32	2.13	3.03	0.99	9.01	...	2.31	15.34	83.79	Waianae
Kaeleku	11.40	3.20	24.20	...	5.60	44.40	0.57	0.16	1.21	...	0.28	2.22	5.09	1.41	10.75	...	2.46	19.71	80.98	Kaeleku
Union Mill	15.00	2.60	....	...	21.00	38.60	0.75	0.13	...	...	1.05	1.93	6.50	1.09	....	...	9.10	16.69	85.60	Union Mill
Halawa	14.20	2.40	....	...	20.80	37.40	0.71	0.12	...	...	1.04	1.87	6.18	1.04	....	...	8.97	16.19	84.72	Halawa
Niulii	12.00	2.80	....	...	22.60	37.40	0.60	0.14	...	...	1.13	1.87	5.76	1.29	....	...	10.80	17.85	81.54	Niulii
Waimea	8.20	1.20	....	...	36.60	46.00	0.41	0.06	...	...	1.83	2.30	3.09	0.44	....	....	13.82	17.35	85.45	Waimea
Olowalu	6.60	0.80	25.60	...	22.00	55.00	0.38	0.04	1.28	...	1.10	2.75	2.45	0.29	9.55	...	8.17	20.46	82.61	Olowalu

Sugar Prices

96° Centrifugals for the Period Sept. 17 to Dec. 12, 1928.

Date		Per Pound	Per Ton	Remarks
Sept.	17, 1928	4.02	80.40	Cubas.
"	18	3.99	79.80	Cubas.
"	19	3.96	79.20	Cubas.
"	20	3.91	78.20	Cubas, 3.93; St. Croix, 3.89.
"	21	3.96	79.20	Cubas, 3.96, 3.99; Porto Ricos, 3.93.
"	24	3.99	79.80	Cubas.
"	25	3.93	78.60	Cubas.
"	26	3.945	78.90	Cubas, 3.93, 3.96.
"	27	3.96	79.20	Cubas.
"	28	3.945	78.90	Cubas, 3.96, 3.93.
Oct.	1	3.93	78.60	Cubas.
"	2	3.90	78.00	Cubas, 3.89, 3.91.
"	3	3.89	77.80	Cubas.
"	8	3.945	78.90	Cubas, 3.93, 3.96.
"	9	3.93	78.60	Cubas.
"	10	3.9467	78.93	Cubas, 3.93, 3.95, 3.96.
"	11	3.93	78.60	Cubas.
"	18	3.96	79.20	Cubas.
"	19	3.93	78.60	Cubas.
"	26	3.895	77.90	Cubas.
"	29	3.86	77.20	Cubas.
"	30	3.83	76.60	Cubas.
"	31	3.80	76.00	Cubas.
Nov.	1	3.77	75.40	Cubas.
"	8	3.83	76.60	Cubas.
"	9	3.91	78.20	Cubas, 3.89, 3.93.
"	10	3.89	77.80	Cubas.
"	12	3.9267	78.53	Cubas, 3.96, 3.89, 3.93.
"	13	3.83	76.60	Cubas.
"	19	3.89	77.80	Cubas.
"	21	3.9333	78.67	Cubas, 3.96, 3.93, 3.91.
"	22	3.89	77.80	Cubas.
"	23	3.90	78.00	Cubas.
"	26	3.94	78.80	Cubas, 3.96, 3.92.
"	27	3.96	79.20	Cubas.
Dec.	5	3.93	78.60	Porto Ricos.
"	8	3.89	77.80	Porto Ricos.
"	11	3.93	78.60	Cubas.
"	12	3.945	78.90	Cubas, 3.93, 3.96.

THE HAWAIIAN PLANTERS' RECORD

Volume XXXIII. APRIL, 1929 Number 2

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Mosaic Disease:

When a cane cutting affected with mosaic disease is planted every shoot of the resulting plant with rare exceptions shows the disease. When a cane plant becomes newly infected with mosaic from the puncture of the insect carrier of the disease, we may find both diseased and healthy shoots or stalks on the same cane plant.

Studies reported in this number confirm earlier findings that healthy sticks from such plants produced healthy shoots, and that diseased cuttings produced diseased shoots in every case.

Notwithstanding the fact that the healthy plants, so propagated, grew alongside the diseased ones, they remained healthy, except for two secondary infections (that is new infections from insect transmission of the mosaic).

The results of this test apply to plantation fields in general. If clean cuttings are planted, the mosaic that appears from new insect infections is relatively small, usually so small as to justify its roguing.

A Cane Disease Chart:

A chart showing the geographical distribution of sugar cane diseases appears in this number.

The list is arranged, from the standpoint of Hawaiian conditions, into a group of primary importance and one of secondary importance. This group applies to present day conditions. When new varieties are substituted for old ones, oftentimes a minor disease assumes primary importance owing to the fact that a new variety may be particularly susceptible. Of the diseases now listed as of primary importance, Hawaii has but two, mosaic and eye spot. The other diseases of this group are gumming disease, leaf scald, Fiji disease, streak disease, sereh, downy mildew, and smut. All of these with the exception of gumming disease are

originally from the Eastern Hemisphere, and thus far none of them is reported in the Western Hemisphere. Gumming disease, the origin of which has been traced to Brazil, has, however, spread to the Eastern Hemisphere and is reported present in Mauritius and Reunion as well as Australia. Mosaic and eye spot have world-wide distribution and are reported to occur in nearly all of the regions where cane is grown.

Pokkah boeng, listed in the group of secondary importance, is given a question mark under Hawaii, as thus far we have not confirmed the findings reported from Java that the malformed tops of this disease are caused by the fungus *Fusarium moniliforme.*

Fourth International Entomological Congress:

In a report on the Fourth International Entomological Congress, which convened at Cornell University, Ithaca, N. Y., August 12 to 18, 1928, is given a general account of the sessions held, and attention is called to some of the prominent features of the Congress and of the important papers presented.

Node Galls on Sugar Cane:

In attempting to trace the cause of stem galls of sugar cane, an experiment was conducted dealing with the sugar cane stalk- or rust-mite. Since the mite belongs to the genus *Tarsonemus,* which contains species which are known to incite gall formation on plants, it is logical to hold it under suspicion. The test was inconclusive. The difficulty of maintaining a mite-free compartment for the check plants was great. The results show the progress of the work. The specific cause of galls on sugar cane remains an open question.

Notes on Pythium:

It has been shown in papers and reports that have already appeared that an important root rot of sugar cane is caused by a *Pythium* fungus. It has also been shown that this fungus under some conditions is very active and that under other conditions it is more or less inactive. The activity has been greater in the presence of decomposing organic materials, such as cane trash, and also in the presence of nitrates from chemical salts.

It has been an open question as to whether the cane trash furnishes certain decomposition products which are poisonous to the cane plant. It is an old theory, as yet unproved, that plants suffer from products of their decay. In this issue is an account of some experiments on this point. It was found that when stable manure was mixed with soil the activity of the fungus in causing root rot was fully as great as when cane trash was used, and perhaps even more so. With both of these materials it was learned that heavy admixtures of them with the soil caused less injury to the cane roots than when smaller amounts were used. This

leads to the idea that the nitrates, or possibly decomposition products of these materials, bring about heavy injury to the cane roots by the fungus up to certain concentrations, but that when these concentrations are increased a retarding effect is produced. This indicates that the higher concentrations are injurious to the fungus that is the primary cause of root rot. "Molashcake" acted in much the same way as rotted cane trash or stable manure. With this material, however, the injury appeared greater and greater as the applications were increased. This point will require further study.

An item of outstanding practical interest in connection with these tests is that the roots of H 109 cane continue to flourish in soils where cane compost brings about such heavy rotting of the Lahaina roots.

It is of interest to note that Lahaina cane makes splendid root growth in a pot containing nothing but cane compost. In soil unfertilized with cane compost or other material the growth is much poorer than in compost but is very fair and free from root rot. Where the soil and the compost were combined half and half, an environment was established particularly favorable to the fungus and here root rot was extremely severe, and the roots were rotted almost as fast as they were formed. In a parallel experiment the H 109 roots were just as good, and in fact a little better, in the half and half mixture of compost and soil than they were where either compost or soil was used alone.

The tests reported are a part of the project of studying soil factors which do injury to cane roots. A part of the project is to determine whether these injurious factors are tending to increase to a point where H 109 or other hardy varieties may show weakness. Thus far the indications are that resistance is very strong in H 109 and that there is little evidence to indicate that this cane will eventually decline. It is true that there are scattered instances where H 109 has shown poor growth on the irrigated plantations, but a careful study of such situations has shown that there is usually some local chemical fault of the soil rather than an environmental condition that favors the fungus and causes it to break down the roots. A high concentration of sodium salts is an example of such a fault, and high magnesium is another. In one or two instances a dearth of phosphoric acid or potash has caused a great weakness in H 109 cane and the situation has been relieved by proper fertilization. There are still a few examples of weakness in H 109 which have not been thoroughly investigated, and it is the purpose of the Experiment Station to cover all such instances of growth failure so that we may have exact information concerning them.

Studies of the Interaction Between Fertilizer and Soils:

This investigation is a continuation of the work previously reported by the chemical department upon the changes taking place in cane soils after the addition of fertilizers. Three phosphate and potash mixtures containing small amounts of nitrogen were added to an acid and a neutral soil. The changes in the displaced soil solution and in soil reaction were determined three days after the addition of fertilizers and again thirty days later. At this time nitrate of soda and

ammonium sulfate were added to the soils and observations were continued for four months longer.

It was shown again that Hawaiian soils have a high fixing power for phosphate fertilizers. No final conclusion can be drawn as to the relative value of superphosphate and raw rock phosphate, until further work in the field in which the composition of the fertilized crop is studied. Valuable information is given as to the changes occurring in an acid and a neutral soil where fertilizer mixtures are applied and later followed by applications of nitrate of soda and ammonium sulfate, supplying equal amounts of nitrogen.

Sulphur as a Fertilizer:

In only one section of the islands, namely the Kau district of Hawaii, has sulphur been shown to be of value as a fertilizer. Its reaction toward the soil complex must be preceded by its oxidation and this oxidation is brought about by certain bacteria known as sulphofying bacteria which are present in many soils. The readiness with which a soil will oxidize sulphur varies and is usually referred to as its sulphofying power. Following or during the process of oxidation many soil properties may be affected. A number of these are discussed.

The sulphofying power of a number of Hawaiian soils and the conditions under which sulphur should be most active have been determined. It is shown that failure to get response to sulphur in other island districts is not due to a lack of sulphofying power of the soil.

Nitrifying Power of Soils:

The availability of all forms of nitrogen other than nitrate depends upon the ability of certain soil bacteria to convert these forms of nitrogen into nitrate. This property, which is known as the nitrifying power of the soil, is usually determined in the laboratory, at laboratory temperatures and under well-aerated conditions, which represent a favorable environment for the activity of the bacteria. Such an environment is far removed from actual field conditions, especially during the latter stages of cane growth when the cane "covers in", and the soil becomes packed, thus reducing aeration and temperature, as well as sunlight, to a minimum.

The effect of these factors upon nitrification has been studied and the reduction in soil temperature and aeration has been shown to materially affect the nitrification process. Caution must therefore be exercised in applying nitrification tests to field conditions.

Seedling Varieties at Ewa:

Other publications have shown from time to time the thorough and systematic way in which the Ewa Plantation Company has dealt with questions of irrigation and questions of fertilization. In this number is an account of the painstaking care in which the large number of seedling varieties have been tested and retested

at that plantation, the poorer ones being discarded, the better ones being held for further trial.

Cane Ripening Experiment:

We report in this number the results of a cane ripening experiment at Honolulu Plantation Company.

The experiment was located at an elevation of about 250 feet. The soil was a red silty clay loam of fair depth.

The results indicate a slight gain in cane yields up to 44 days after the last irrigation, and then remained practically constant. The yield of sugar increased rapidly up to 65 days, and more slowly up to 90 days, after which it declined.

The yield of sugar per acre per month increased rapidly up to 65 days, after which it declined, at first slowly then rapidly. The Brix showed a continuous increase, at first rather rapidly then more slowly. Polarization increased rapidly up to 65 days, after which it declined gradually. Purity improved up to 65 days, then showed a slow decline up to 90 days, then a more rapid decline.

Per cent moisture in cane declined slightly and gradually. Soil moisture declined to the wilting point, then rose again as the result of showers, and finally declined again to the wilting point.

Nitrate nitrogen in soil first declined and then increased. P_2O_5 and K_2O in juice showed a slight increase, especially at first; this increase is due most likely to an increase in concentration of cell sap due to drying out.

Additional Studies of Weather and Yields:

Because of the equable climate, the production of sugar in these islands is not subject to tremendous fluctuations from year to year as in Louisiana and Cuba. Nevertheless, the question often arises, "Do the small variations in the local weather conditions have appreciable influence on sugar yields?" The present series of weather studies were undertaken mainly to answer this question.

In our first paper, we studied the influence of weather changes on the yields of a typical unirrigated plantation, namely the Pepeekeo Sugar Company. To start with, we picked out a group of years in which the yield per acre was outstandingly high, and another in which the yield was low. By comparing the monthly distribution of rainfall and temperature in these two groups of years, we discovered that the high-yield years had ideal conditions for growth, the rainfall was abundant in the summer months and meagre in the ripening and harvesting period, while in the poor years it was the other way around. In the matter of warmth also, the high-yield years had uniformly higher temperatures than the low-yield years. Correlation studies further showed the critical importance of high temperature in the first year of the life of a crop and of high rainfall in the summer months of the second year. The study of this plantation proved that even the small changes in the weather conditions had definite relation to yields in an unirrigated plantation.

Do weather changes affect the irrigated plantation in a similar manner? In the irrigated plantation the supply of moisture is, theoretically, ample. Then, the element of weather that should influence, if at all, the yields of such plantations, would be the temperature. In the second paper, we have studied the yields of a typical irrigated plantation, namely the Ewa Plantation Company.

The results of this latter investigation support, in general, our findings at Pepeekeo. It is shown that at Ewa the distribution of irrigation water was more ideal in the case of high-yield years than in the low-yield ones. Also, the high-yield years had uniformly higher temperatures. It is shown that the total amount of water applied per crop had a definite relation to production.

This study also brings out that at Ewa maximum monthly temperature is of more significance than either the mean or minimum temperature. It further suggests the importance of a wide range of daily temperature to high production.

In the light of these findings we can say that ideal weather conditions must have contributed, in part, to the record yields of the last few years.

Cane Growth Studies:

F. M. Anderson, manager of Paauhau Sugar Plantation Company, presents in this issue some notes on a new and unique way of handling growth measurements. Volume growth was determined on every stalk in a 30-foot line. By test he then determined the weight of a cubic inch of cane and was thus enabled to arrive at a close estimate of the number of tons of cane per acre produced each month in the various treatments. We feel that this method has distinct value.

International Society of Sugar Cane Technologists:

A communication from the Preparation Committee of the forthcoming Java conference, giving a tentative program and list of subjects to be discussed.

Cane Factory Sanitation:

A description of the harmful bacteria found in our factories and the practical measures involved in reducing losses by bacterial action to the minimum.

Colloids:

A clear statement upon what is meant by "The Colloidal State of Matter" is taken from another journal.

The Germination of Healthy and Mosaic-Affected Cuttings Selected from the Same Stool

By J. P. Martin

It has been established for many years that mosaic-affected cuttings will, upon germination, produce plants affected with the disease on an average of ninety-nine times out of one hundred. Because of this fact it is extremely essential to select and plant only healthy cuttings.

Cane is planted in Hawaii, as a rule, during the early spring months in conjunction with harvesting so as to secure top "seed," or cuttings. Excellent results in mosaic disease control in the past have been obtained through the selection of cuttings free from mosaic disease by training the seed cutters to recognize the difference between healthy plants and plants affected with the disease. In cutting seed it is often advisable to have a competent man with the cutters to keep a rigid check on the men in order that they do not become careless and include cuttings from diseased plants.

By frequent inspections of the fields when the cane is young it is possible to note and record the degree of infection in each field and later avoid taking seed for planting from those fields affected with the disease at harvesting time. Where there are only a few cases of the disease in a field roguing should be practiced so that a healthy stand may be maintained; with this practice seed selection at the time of harvest is not so essential.

If a cutting is affected with mosaic disease at the time of planting the shoots in the resulting stool are usually 100 per cent affected and the shoots or stalks in subsequent ratoons are likewise affected.

In numerous experiments it has been shown that the corn aphis, *Aphis maidis*, Fitch, is capable of transmitting the disease from mosaic-affected grasses to healthy cane plants. So far the corn aphis is the only insect known that actually does transmit the disease to healthy cane after feeding on mosaic grasses. The cane plant is not a suitable host for the corn aphis while certain of the grasses offer very favorable environmental conditions for their livelihood. Since some of the grasses are common carriers of mosaic, the disease is in most cases transferred from the grasses to cane rather than from cane to cane by the insects; therefore, weed control on a plantation aids greatly in minimizing the spread of the disease.

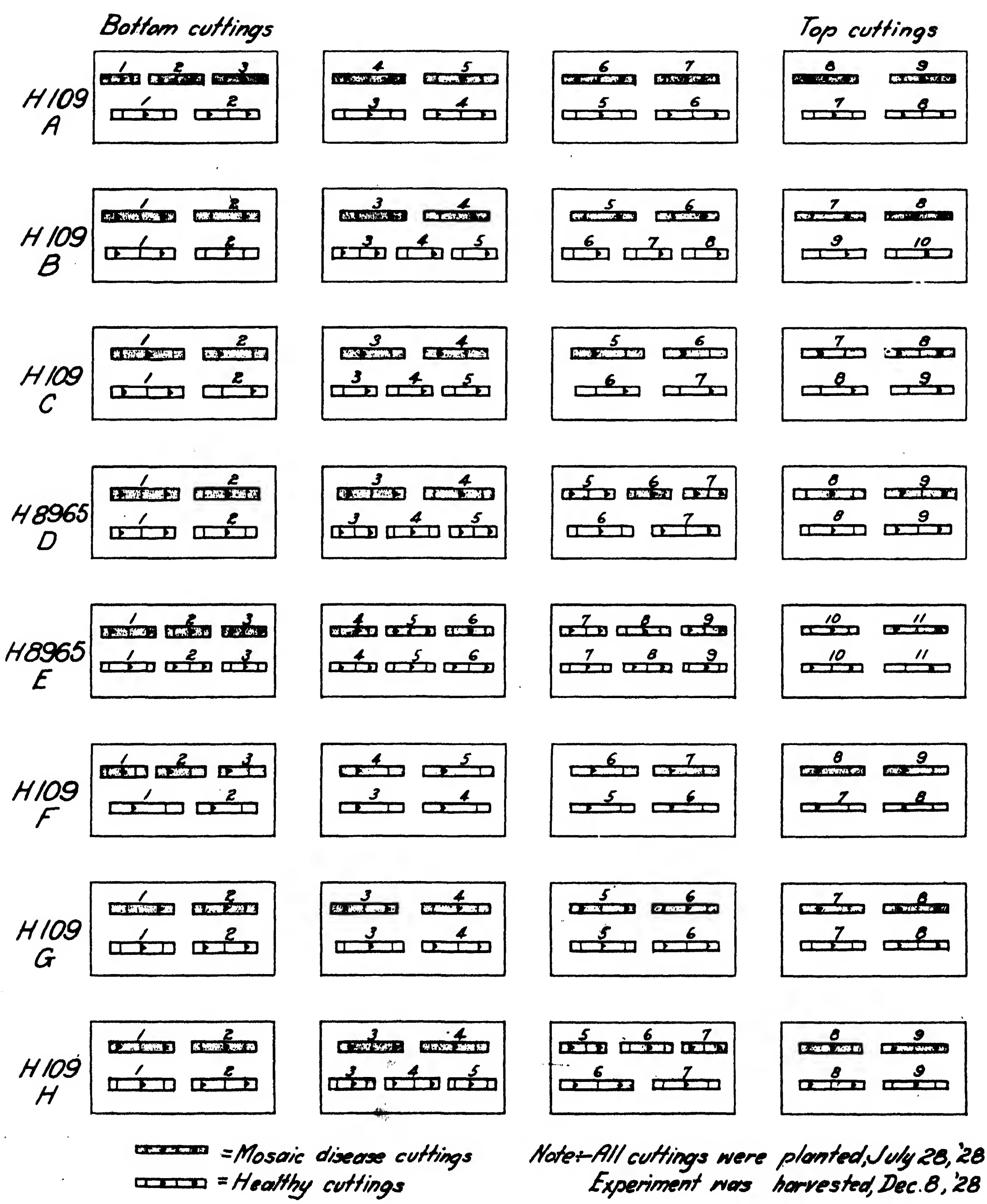
Often cane from healthy cuttings becomes affected with mosaic disease by insect transmission after it has germinated, and it is not uncommon to find both healthy and diseased stalks in the same stool. In roguing or seed selection work the point arises whether it is necessary to discard the entire stool or rogue out only those stalks manifesting the disease. Previous studies have shown that it is necessary to eliminate only the affected stalks and not the entire stool.

The following experiment was carried out at the Waialua Agricultural Company, Ltd., and is merely a repetition of previous studies.* The results obtained

* Lyon, H. L., 1921. Three major cane diseases: mosaic, sereh and Fiji disease. In Experiment Station, H.S.P.A., Bot. Series Bull. Vol. III, part I.

in this experiment confirm those already established regarding the germination of healthy and mosaic-affected cuttings when selected from the same stool.

Eight stools from different plant fields of H 109 and H 8965 were selected which had both healthy and mosaic-diseased stalks. The cane in each case was from eight to ten months old. One healthy and one diseased stalk were carefully

THE GERMINATION OF HEALTHY AND MOSAIC AFFECTED CUTTINGS SELECTED FROM THE SAME STOOL

cut from each of the eight stools. The sixteen individual stalks finally chosen were cut into two- or three-eye cuttings, and eight to eleven seed pieces were obtained from each stalk. The cuttings were planted in small wooden flats, having the following inside dimensions: 13 inches wide, 24 inches long, and 5 inches deep. The soil used in these flats was virgin top soil which was obtained from an excavation in Field Valley 3 of Waialua plantation. Each flat contained two or three cuttings of a healthy and of a mosaic stalk. Care was exercised in planting so that all cuttings were in order of the natural growth of the stalks. A detailed plan of the arrangement regarding the method of planting is shown in the figure accompanying this article. The experiment was started July 28, 1928, and harvested December 8, 1928. At the end of the experiment the growth of the cane was being slightly retarded because of the small amount of soil contained in the flats.

Every eye germinated in both the healthy and diseased cuttings. Mosaic disease was observed in every shoot from the diseased cuttings as soon as the small leaves began to appear. Every shoot from the healthy cuttings was free from the disease for two months; however, at the end of this period mosaic disease was found in two individual shoots from two separate seed pieces. No doubt these two cases developed from direct insect transmission because the small flats were close together and the leaves of the healthy and diseased plants freely intermingled at all times.

At the termination of this experiment only these two cases of mosaic were evident in the plants from the healthy cuttings while every plant grown from the mosaic-affected cuttings was badly affected. The results of this experiment are not entirely conclusive because the cane plants did not mature but the evidence secured clearly points out the value of careful seed selection during the planting season as an effective measure in controlling the disease.

The table presented in this article indicates the number of cuttings and the number of eyes planted from each stalk. It also gives the percentage of shoots affected with mosaic disease immediately following germination.

Variety	No. of Cuttings Planted from each stalk		No. of Eyes Planted from each stalk		Percentage of Shoots Affected with Mosaic Disease upon Germination	
	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased
H 109—A	8	9	24	27	0	100
H 109—B	10	8	23	18	0	100
H 109—C	9	8	19	18	0	100
H 8965—D	9	9	27	27	0	100
H 8965—E	11	11	32	33	0	100
H 109—F	8	9	16	19	0	100
H 109—G	8	8	24	22	0	100
H 109—H	9	9	27	27	0	100
Total	72	71	192	191		
Average					0	100

Summary

In the above experiment every shoot upon germination from the mosaic-affected cuttings was diseased while every shoot from the healthy cuttings was free

from the disease. At the end of two months, two cases of mosaic disease were observed in plants from the healthy cuttings which no doubt were due to insect transmission.

Recommendations for Controlling Mosaic Disease

Mosaic disease may be greatly reduced by:

1. Selecting and planting only healthy cuttings. It is possible to practice this measure by instructing the men who are cutting the seed, as to the difference between healthy and mosaic plants and also by having a man in charge of the seed cutting gang to see that the seed cutters follow instructions.
2. Keeping the fields free from weeds at all times even though some of the grasses are not affected with the disease. Healthy as well as mosaic grasses harbor the corn aphis.
3. Roguing affected plants as they appear in the fields. Periodic inspections of young cane are extremely valuable in locating the disease areas. It is very difficult to examine old cane for the presence of mosaic.
4. Practicing any cultural method that stimulates a quick closing in of the cane, thus reducing the weeds and in turn lowering the cost of weeding.
5. Planting resistant varieties in those areas badly affected with the disease; an example of this control measure in Hawaii is the substitution of D 1135, a resistant cane, in place of Striped Tip which is very susceptible to the disease.
6. Avoiding the practice of growing corn near a cane field because of the large number of corn aphis continuously migrating to the cane fields. Corn is one of the common hosts harboring mosaic disease.

A Distribution Chart of Sugar Cane Diseases of the World

This chart of the distribution of sugar cane diseases is now issued after correspondence with about thirty pathologists, including pathologists resident in the following countries:

Hawaii, Australia, Formosa, Philippine Islands, Java, India,
South Africa, Louisiana, Cuba, Porto Rico, British West Indies,
Brazil, Argentine and Peru.

In a few minor cases, where there has not been complete agreement as to the diseases of any particular country, we have relied upon the report of the resident pathologist.

The division of these diseases into "Diseases of Primary Importance" and "Diseases of Secondary Importance" is based solely on their relation to the Hawaiian Islands.

It has been impossible to list all the diseases reported in response to this questionnaire, and minor diseases which are restricted to one country, and for which the causal agent has not been described, have not been recorded.

All fungous root diseases reported have been placed into one of the three groups listed on the original chart.

We will welcome information concerning any alterations or additions to the chart which may be necessary in the future.

ARTHUR F. BELL.

Report on the Fourth International Entomological Congress

By O. H. SWEZEY

On August 12-18, 1928, the Fourth International Entomological Congress convened at Cornell University, Ithaca, New York. Previous sessions of this Congress were held in Europe, the first at Brussels in 1910; the second at Oxford in 1912; and the third at Zurich in 1925. This was the first time that it was held west of the Atlantic. Six hundred and twenty-five delegates were in attendance, representing thirty-eight different countries, 134 being from foreign countries. It was a much larger number than had attended the previous meetings, in fact, it was the largest and most important convention of entomologists that has ever occurred. F. Muir and O. H. Swezey were in attendance from the Experiment Station, H. S. P. A., and E. P. Mumford, in charge of the Entomological Survey of the Pacific Islands, was also present.

Dr. L. O. Howard, of the U. S. Bureau of Entomology, was president of the Congress, while the secretary was Dr. Karl Jordan, of the Zoological Museum, Tring, England. The lecture halls of various buildings of Cornell University were made available for the sessions of the various sections, the general meetings and evening lectures, as well as for social functions. Delegates were accommodated in dormitories on the campus, and an excellent cafeteria provided meals. A general meeting was held each day, usually in the forenoon, with lectures, papers or discussions of interest to all, while the afternoons were mostly devoted to meetings of the various sections where programs were carried on pertaining to each particular section. The list of sections embraced: Nomenclature and Bibliography; Systematic Entomology and Zoogeography; Morphology, Physiology, Embryology and Genetics; Ecology; Medical and Veterinary Entomology; Forest Entomology; Apiculture; Cereal and Truck Crop Insects; Citrus Fruit Insects; Deciduous Fruit Insects; Cotton Insects; Insecticides and Appliances.

Papers with reference to sugar cane pests were included in the section on Cereal and Truck Crop Pests. Mr. Muir presented a paper on: "The problem of biological control in Hawaii," and Mr. Swezey a paper on: "Present status of certain insect pests under biological control in Hawaii." The latter was illustrated with lantern slides of the important pests and their introduced parasites. Much

NAME OF DISEASE	CAUSAL AGENT	Hawaii	Fiji	Australia	Formosa	Philippines	Java	India	Mauritius and Reunion	Egypt	South Africa	Mexico	Central America	Louisiana and S. E. U. S. A.	Cuba	Santo Domingo	Porto Rico	B. W. Indies and North Coast South America	Brazil	Argentine	Peru
Diseases of Primary Importance:																					
Gumming disease	*Bacterium vascularum*			x					x								x	x	x		
Leaf scald	*Bacterium* sp.		x	x	?	x	x														
Mosaic	Probably a filterable virus	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
Fiji disease	Undetermined		x	x		x															
Streak disease	Probably a filterable virus							x	x	x	x										
Sereh	Undetermined				x		x														
Downy mildew	*Sclerospora sacchari*		x	x	x																
Smut	*Ustilago scitaminea*				x	x	x	x	x												
Eye spot	*Helminthosporium sacchari*	x	x	x	x	x	x	x	x		x		x		x	x	x	x	x		x
Diseases of Secondary Importance:																					
Red Stripe	*Phytomonas rubrilineans*	x		?			?							?	x						
Polvillo	Undetermined																		x	x	
Buñga	*Aeginetia indica*				x	x	x	x													
The cane-killing weed	*Striga* sp.			x				x			x							?			
Dry top rot	*Plasmodiophora vascularum*																x	x			
Rust	*Puccinia kuehnii*		x	x	x	x	x	x													
Ring spot	*Leptosphaeria sacchari*	x	x	x	x	x	x	x	x		x				x	x	x	x	x	x	x
Yellow leaf spot	*Cercospora kopkei*				x	x	x		x						x		x	x			
Red leaf spot	*Eriosphaeria sacchari*						x											x			
Brown leaf spot	*Cercospora longipes*							x							x		x	x	x		
Black leaf spot	*Phyllachora sacchari*					x	x	x													
Cytospora leaf spot	*Cytospora sacchari*							x							x		x			x	
Pestalozzia leaf spot	*Pestalozzia fuscescens*					x	x	x													
Phyllosticta leaf spot	*Phyllosticta sacchari*																			x	
Banded sclerotial leaf disease	*Mycelia sterilia*			x	x	x	x	x													
Sticking of leaves	*Myriogenospora aciculisporae*																		x	x	
Red rot of leaf sheath	*Scleriotium rolfsii*	x	x	x	x	x	x	x						x	x		x	x	x		
Red spot of leaf sheath	*Cercospora vaginae*				x		x		x						x		x	x	x		
Iliau	*Gnomonia iliau*	x		x										x	x				x		
Pokkah boeng	*Fusarium moniliforme*	?					x														
Red rot	*Colletotrichum falcatum*	x	x	x	x	x	x	x	x			x		x	x	x	x	x	x		
Wilt	*Cephalosporium sacchari*					x		x			x							x			
Collar rot	*Hendersonia sacchari*							x													
Pineapple disease	*Thielaviopsis paradoxa*	x	x	x	x	x	x		x			x		x	x	x	x	x			
Rind disease	*Pleocyta sacchari*	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x
Tangle top	A mechanical injury	x		x	x	x	x							x	x		x				
Stem gall	Undetermined	x	x	x	x	x	?							x	x						
Cold chlorosis		x		x	x			x			x	x		x	x		x			x	x
Lightning top rot	Caused by direct lightning strike	x			x		x										x			x	
Root Disease or Growth Failure Complex																					
Pythium root rot	A fungus of the genus *Pythium*	x			x		x							x	x		x	x			
Other root rots of active parasites	*Rhizoctonia sp.* etc.	x					x	x						x	x		x	x			
Root rots of weak parasites	*Marasmius sacchari*, etc.	x	x	x	x		x	x	x					x	x		x	x		x	
Nematode injury		x		x	x		x	x						x	x		x				
Macrofauna injury	Springtails, snails, centipedes, etc.	x		x	x							x		x	x						x
Growth failure from high salt concentration in the soil		x			x		x	x							x	x	x			x	x
Growth failure from aluminum soil toxicity		x																			
Growth failure from unfavorable Mg/Ca, or Na/Ca ratios		x													x		x	x	x		
Chlorosis due to excess CaO, or deficiency of Fe or Mn		x					x								x		x	x			

x Indicates reported presence.
? Indicates presence probable but not confirmed.

interest was shown in the results attained in Hawaii in this line of work. There were other papers dealing with parasite introduction and other phases of work with insect parasites. It is worthy of note that biological control of insect pests is increasing in importance and being undertaken pretty generally by economic entomologists throughout the world.

In a paper by D. L. Van Dine, of the Tropical Plant Research Foundation, Cuba, over fifty parasites of sugar cane moth borers were listed and their geographic distribution given. This furnishes valuable information for those desiring to undertake parasite introduction, in knowing which is the most convenient locality to attempt this introduction from; also, cooperation was suggested in the inter-exchange of parasites working towards a more general spread of the most useful of the parasites.

Methods were given in a paper by W. E. Hinds, of Baton Rouge, Louisiana, for rearing during the winter, moth borer egg-parasites on a large scale so as to have large numbers ready for liberation at the proper time earlier in the season than these parasites are able to show their effectiveness. By this means parasitism was increased in one season from 88 to 98 per cent. A very productive method has been worked out for breeding the egg-parasite *Trichogramma minutum* to be used in this way. S. E. Flanders has also developed a method of rearing the same parasite on an immense scale for liberation on walnut trees in southern California to parasitize the eggs of the codling moth which has of recent years become a pest of walnuts in that region.

G. N. Wolcott maintained that the most hopeful control of moth borer in Porto Rico is the non-burning of trash. This is on account of its allowing the survival of the egg-parasites in sufficient numbers to become immediately effective on the eggs of the first brood of moth borers in the spring.

There were several papers on the European corn borer which was first known in the United States eleven years ago and has rapidly spread over a great area. In much of this area it has not become a serious pest, while in other places it practically ruins the corn crop. Many millions of dollars are being spent in endeavors to check the spread of this pest and in control measures. It has been found that parasitism by native parasites is only about one per cent. Twelve species of parasites have been introduced from Europe, 2,500,000 of them having been liberated. Of these, seven species have been found to have become established, and it is hoped that benefits will be derived from them. No kind of insecticide control method has been found satisfactory. Cultural practices have been found most useful, especially the cutting of the corn crop and shredding it for ensilage, and burning or otherwise destroying the stubbles so as to destroy any corn borers therein. On one day there was an excursion to the New York State Agricultural Experiment Station at Geneva and most of the forenoon was occupied with field demonstrations of farm machinery that have been devised for handling the corn crop, or otherwise connected with its culture, and that were destructive to the corn borer. One was a plow that thoroughly buries all stubbles and stalks in the plowing process. Another was a machine to pass over the field and with a series of rapidly revolving disks, the stubbles in the ground were torn to shreds, thus destroying any corn borers that might be therein. Various kinds of corn cutters and harvesters were shown, some to cut the stalks and save them for fodder or ensilage, and

others to merely cut the old stalks and let fall on the ground for burning; a special rake for gathering the fallen stalks in windrows for burning; and a burning machine which with a series of flaming torches burned everything clean when passed over a field. All of these bring sure destruction to the corn borer, but the expense of using, no doubt, will operate against their very extensive use by corn growers, particularly those farming on a small scale. In 1927, $10,000,000 were spent in an attempt to check further spread of the corn borer, and it was demonstrated that it could not be done; hence, it is inevitable that this pest will before many years occupy the whole of the corn-growing area of the United States. It is to be hoped that parasitic control will become effective before that time comes.

Hessian fly control by parasites is not successful in the United States. There are twenty-nine species of parasites known on this pest there, and often there is a parasitism of 90 per cent, yet even then there are enough left to be very detrimental. The Hessian fly is a tiny midge which attacks young wheat plants. The best methods of control are: destruction of all straw and stubble and especially the destruction of all volunteer wheat in the autumn, and the practice of late fall sowing of wheat.

A number of papers dealt with the present status of entomological work in several of the important agricultural sections of Europe, giving their main crop pests and means of control. There were numerous other papers of less importance with reference to the pests of cereal and truck crops.

In each of the several sections dealing with economic entomology there were numerous papers appropriate to the section. As one could only select here and there a section to attend, according to the items of interest on the different programs, it is impossible to report on most of them.

Papers in the section on Deciduous Fruit Insects dwelt chiefly on the codling moth and its control in the various regions, and with the problems of arsenical residues. So much spraying with poisons has to be done to kill off the larvae, that there is apt to be a dangerous amount of poison left on the fruit. Thus it is necessary to devise some economical method of washing off the poison, or else find an appropriate insecticide that does not leave poison on the fruit. The green Japanese beetle in New Jersey and vicinity continues to spread and is a pest not only to fruits but most all kinds of truck crops and ornamentals. It was not so bad the past two years. At Moorestown, New Jersey, is a large laboratory and offices of the staff carrying on work against this beetle. Probably it is in connection with this pest that parasite introduction is carried on on the largest scale. For several years parasites have been introduced from Japan and China on a very large scale, and breeding is being carried on at the Moorestown laboratory. Several parasites have been introduced, and two of them are known to have become established.

In the section on Citrus Fruit Insects the papers were chiefly on control of scale insects, both by the biological method as well as spraying and fumigating.

In the section on Cotton Insects, papers dealt chiefly with the cotton boll-weevil and the pink boll-worm.

In Forest Entomology, termite work and control was treated; also the activities of the gypsy moth laboratory in the work of control of the gypsy moth and the brown-tail moth in the New England States, both by introduction of parasites and

insecticides. The introduction of parasites from Europe has been carried on for about twenty years and several have become established and quite widely spread. Other forest pests were dealt with, and there were several papers by different European entomologists giving an account of the important forest insects of their respective countries.

In the section on Apiculture were practical papers relating to care of bees and honey production, some of them dealing with the diseases which bees are subject to.

Papers in the Medical and Veterinary Entomology section dealt largely with insects as carriers of diseases both to man and beast, and one session was devoted entirely to papers on mosquitoes and their control.

In the section on Nomenclature and Bibliography there was much discussion on the methods of naming and classifying insects and recording them, catalogues, etc. There is great lack of uniformity in these matters and difficulty in making rules for general observance. The great need of more and better insect catalogues was stressed.

Under Systematic Entomology and Zoogeography were several papers on interesting insect fauna of various parts of the world; and a forum on "Problems of Taxonomy." Dr. F. Silvestri had a paper on "The relation of taxonomy to other branches of entomology." The taxonomist deals with the classification of insects, and the economic entomologist as well as others must look to him for the correct determination of the insects (pests or parasites) that they are concerned with. It is of greatest importance, for example, in dealing with a new pest, to find out definitely what it is and where from, so as to know where to look for more information regarding its habits or importance, and where to go for its natural enemies. Much confusion has sometimes resulted from mis-identification of pests as well as of parasites, particularly in making the distinction between primary and secondary parasites. "The need of an International Institute of Entomology" was a subject that received much discussion, as was also the disposition of the "type" specimens of described species. The enormity of the task of the taxonomists was pointed out by one speaker who gave 350,000 as the number of species of insects that are already known and considered to be not more than one-tenth of the existing species.

At the general sessions the papers were of wide range of interest and importance, treating of very diverse phases of entomology. At the opening meeting, Dr. L. O. Howard in his presidential address, stressed the importance of entomology as a subject of study, and of the dominant place that the insects have in the whole animal kingdom, and the difficulty that man has to gain ascendency or control over them. He made an urgent plea for greater recognition in the schools, maintaining that entomology should have a position of rank at least along with botany and zoology, rather than being considered as a minor part of zoology.

Dr. C. L. Marlatt, in a paper on "Restrictions enforced by the United States on entry of foreign plants and plant products for the purpose of excluding new and dangerous pests," gave an excellent presentation of the situation by which the United States has been continually receiving destructive insect pests from Europe, and the necessity of the formulation of restrictive laws for prevention of this. In recounting the difficulty of getting legislation in this line, he listed several im-

portant pests that had gained entrance during a period of several years while attempts were being made to secure legal restrictions against them.

Dr. W. M. Wheeler, well known as the world authority on ants, gave a paper on some interesting relations of certain plants and ants. He pointed out conclusively that certain structures (domatia) on plants, that are regularly occupied by ant nests, have arisen independently of the insect relations, and he classed as "bunk" the idea that these structures have developed through natural selection as though it were a benefit to the plant to provide a nesting place for the ants. "The plants have no more need of their ants than dogs have of their fleas."

Dr. W. J. Holland, of the Carnegie Museum, presented a paper on "The mutual relations of museums of science and taxonomic specialists." It is recognized that an important function of the museum is to provide specialists for determining material sent in, and the working up of collections for others not favorably situated to do so. In discussion, the plan was suggested that specialists in particular groups of insects should be circulated, or as it were passed around from one museum to another working up in each their collections of the groups with which each specialist is familiar. It happened that the day Dr. Howard presented his paper was his eightieth birthday. A pause in the program was taken for extending him appropriate congratulations. He was elected as honorary member of the Congress. Dr. S. A. Forbes, who was in attendance at the Congress and was eighty-four years old, was also elected to honorary membership.

"Insect inhabitants of the upper air" was presented by Dr. E. P. Felt, in which he outlined methods of making observations and determining to what extent insects may be carried by air currents, or may themselves disperse to great distances.

In a paper on "Biological control of noxious weeds," Dr. R. J. Tillyard gave an account of what has been done in Australia in attempts to control the prickly pear by introduction of insects and diseases from America. One species of prickly pear has already become controlled by the introduction of a scale insect that is confined to the one species of plant. A moth has been introduced from America the caterpillars of which are specially destructive and are already successfully killing off the worst species of prickly pear in places where the insect has already become established. Photographs were shown illustrating the destruction to the cactus by this insect.

Another paper on "Insect control of noxious weeds" by Dr. A. D. Imms gave an account of work along this line in New Zealand, particularly in attempts to introduce from England a small weevil which destroys the seeds of gorse. There has also been considerable search to find insect enemies of the blackberry that would be safe to introduce against this pest plant.

Dr. Karl Jordan, the world authority on fleas, gave a paper on "Problems of distribution and variation of North American fleas." He pointed out that 131 species of fleas are known in America north of Mexico, and estimates that the number will increase to over 200 when they are better known, and that in the world at large there are probably over 800 species.

Dr. Rimsky-Korsakov, of Russia, had a paper on "Freshwater-living Hymenopterous parasites in Russia." He discussed some small parasites related to our sugar cane leafhopper egg-parasites, which go below the surface of the water to parasitize the eggs of certain aquatic insects.

The above gives an idea of the range of papers at general sessions.

At opportune times excursions were arranged for so that the foreign entomologists could visit some of the interesting collecting grounds of the region, and to places for special insects. Other excursions and picnics were to scenic places of interest, there being a great variety in the interesting topographical features of the region surrounding Cornell University.

On an evening towards the end of the Congress, a banquet was held, attended by 350. Dr. Howard was toastmaster and called on representatives of thirty-one countries, each of whom spoke in his native tongue.

At the closing session it was announced that the Fifth International Entomological Congress would be held in Paris in 1932.

Notes on *Tarsonemus spinipes* Hirst in Its Possible Relation to Sugar Cane Node Galls

By C. E. Pemberton

The sugar cane stalk- or rust-mite *Tarsonemus spinipes* Hirst is closely related to a number of mites of the same genus in other parts of the world which are responsible for the production of galls on several different plants. *Tarsonemus pallidus* Banks, a gall-mite in the United States, attacks cyclamen plants, causing distorted and thickened leaves. We quote Nathan Banks,* an authority on acari, regarding several other species of *Tarsonemus* of economic importance, as follows: "*Tarsonemus latus* Banks causes galls on the main shoots of mango plants. *Tarsonemus canestrinii* Marchal, produces small rounded galls on several European grasses. *Tarsonemus spirifex* Marchal forms elongate swellings on oats. *Tarsonemus waitei* Banks attacks the growing terminal twigs of peach trees and turns them into elongate, blackened, and distorted galls with many small lateral twigs and leaves growing from them." This last reference is of particular interest to us because of the similarity of gall growth of many gall types appearing on certain of the seedlings propagated here in recent years.

Tarsonemus oryzae Targ.-Toz., according to Quaintance†, infests the culms of rice plants in Italy. He states that the development of "numerous very fine threads or fibres" on the plant "are thought to be caused by this acarid." In the *Planters' Record* for October, 1926, page 493, H. L. Lyon refers to node galls on cane in Hawaii assuming in certain cases forms which include "threads."

Our species in Hawaii is that of the West Indies, according to recent comparisons with type specimens from Barbados, by Susan Finnegan, of the British Museum. Banks states that it attacks the sugar cane stalk in the West Indies, giving entrance to injurious fungi. No mention is made in literature, however, of its possible relation there to node galls.

* Report No. 108, pp. 108-109, Office of the Secretary, U.S.D.A. December, 1915.
† U.S.D.A. Bureau of Entomology Bulletin 97, Part VI, p. 111.

Where species of *Tarsonemus* have been credited with the appearance of galls on various plants, no explanation has been given as to the exact part they play in their development. It is uncertain whether they follow certain bacterial infection, simple mechanical irritation or tissue stimulus from injections, while feeding of substances of an irritating or toxic nature.

During October, 1927, a series of examinations were made of several seedlings, particularly of the U.D. series, on which node galls commonly occur, to determine if possible any correlation between the stalk-mite and the presence of node galls. This was done by Dr. Lyon and discussed by him.* He found that "galls often begin their development and, in some cases, attain a considerable size, before the acari penetrate to their locations." In a large series of careful examinations we have also failed to find mites as close to the growing point as galls sometime occur. Lyon† found some cases in which "incipient galls could be easily detected on the tender tissues within half an inch of the growing point of the stem."

In the examinations of gall-canes in October, 1927, *Tarsonemus* adults were frequently found on tender stem tissue within 1½ inches of the growing point. As this stem tissue was very soft and young, it was yet too soon for the characteristic blister galls made by the feeding of the mite to have developed, and unless the few mites which had penetrated so far up the stalk were not actually seen one could readily conclude that they had not as yet been there. It is possible that they may uncommonly penetrate up on the tender stalk within a half-inch of the growing point. The mature, pale-yellowish, migrating females of this mite, move about quite actively.

Certain of the U.D. canes on which galls appear in abundance are not particularly susceptible to *Tarsonemus* attack. On some, *Tarsonemus* are comparatively uncommon. This fact would tend to discourage the probability of *Tarsonemus* being the causative factor or vector of such factors.

In view of the known record of several species of *Tarsonemus* in other parts of the world as gall-producing mites, an experiment was started on November 19, 1927, in an effort to correlate our sugar cane stalk-mite with the development of node galls on cane in Hawaii. The variety U.D. 13 was used because of the frequency with which node galls appear on this cane.

Seed of U.D. 13 was cut on November 10, 1927, at the Manoa Valley node gall plot, care being taken to select seed only from a stool showing unusually heavy gall growths. This was soaked for thirty minutes in a 1 per cent solution of Uspulun to insure sterilization and then vigorously sprayed, especially around and under the eyes, with Volck, an oil emulsion insecticide, to which soap was added to improve its penetrating qualities. The Volck was used at a dilution of one tablespoonful to one gallon of water. This treatment gave fair assurance that all acari would be killed.

The seed was then soaked in water for forty-eight hours and planted in sterile soil in pots in ten separate cages, using three eyes per cage. The inside of each cage was also thoroughly sprayed with a strong solution of creolin. Each cage was isolated from the ground on pans of water. Five of the cages were then imme-

* *Planters' Record*, October, 1926, p. 505.
† *Planters' Record*, October, 1926, p. 495.

diately sealed with adhesive tape over all cracks about the door, etc., and the pots from then on were watered through a cotton-plugged tube leading in from the outside.

As soon as the cane was up from 1 to 2 feet in the other five cages a quantity of *Tarsonemus* adults and young were placed on the young shoots. This was on January 7-9, 1928. In cage No. 5, in addition to inserting *Tarsonemus,* a quantity of cane mealybugs, *Trionymus sacchari,* were also put in. This was done through the suggestion of C. W. Carpenter and Arthur F. Bell, who both felt there might be some possibility of this mealybug operating as the insect vector or causative agent of the node galls. Though this mealybug does not penetrate upward on the tender stalk as close to the spindle as the *Tarsonemus,* still it does, while in a very young stage, appear fairly high on the stalk beneath the leaf sheaths.

The seed pieces used in check Nos. 6 and 7 bore many galls around the eyes.

(April, 1928, prior to Mr. Pemberton's departure for New Guinea.)

Results of Experiment

All of the above series of cages were examined September 17, 1928, by Messrs. Lyon, Carpenter, Swezey, Muir and Van Zwaluwenburg. Two cages had no growth of cane, as the seed had apparently failed to germinate. In the other cages the leaves were up against the top of the cage. Results of examination are tabulated below:

Cage No.		Tarsonemus	Mealybugs	Node Galls
1	Supplied with *Tarsonemus*	Traces	Very abundant	Few
2		None	Few	Moderate
3		One trace	Few	Few
4		No trace	None	Moderate
5	Supplied with *Tarsonemus* and mealybugs.	Few traces	Moderate	Moderate
6	Checks; Seed had many node galls around eyes	On 1 leaf sheath	Few	Very abundant
7				
8		Few traces	Few	Moderate
9				
10			Very abundant	Abundant

Note: No cane grew in Nos. 7 and 9.
Sugar mites in thousands in dried-up honeydew from mealybugs in No. 10.

As to be seen from the table, node galls were present in greater or less abundance in all cages where the cane had grown. One of the check cages had more node galls than any other cage, but aside from this there was hardly any difference in regard to node galls between the check cages and the other cages. As to the stalk-mite, they were scarce in all cages. Only slight traces were found in any of them. In two instances they were in check cages where none had been placed. There was a moderate infestation of mealybugs in the cage in which they were put; they were very abundant in two other cages; and a few in four other cages, there being but one cage having no mealybugs on the cane.

The experiment has not turned out conclusively, on account of the failure in controlling the stalk-mites and mealybugs. The stalk-mite gained entrance to two cages in which they were not put, and did not develop to any extent in those cages supplied with them. Mealybugs gained access to six cages besides the one supplied with them. It is very apparent, however, that the development of node galls in the cages was not dependent upon the stalk-mite. The latter was so scarce, and the galls were so prevalent that it is rather to be inferred that the tendency to produce galls was inherent in the cane itself, the cuttings all having been taken from a stool of cane whose stalks showed a heavy gall growth.

(O. H. S.)

(November 1, 1928).

The above experiment, though unsatisfactory and not clear-cut enough to give us absolute conclusions, would favor the belief that gall-mites are not the causative agents of node galls. Cage No. 10 especially strengthens this view. It is within the bounds of possibility, however, that even a few undiscovered mites would be sufficient to start a gall infection that would go on of itself, to conspicuous proportions, in the absence of further mite infestation or development, or even if the few mites once on the cane died out entirely.

(C. E. P.)

(Port Moresby, New Guinea, January 14, 1929.)

Notes on Pythium Root Rot

V

By C. W. Carpenter

In the fourth article of this series* evidence was cited from which it was inferred that susceptibility of Lahaina cane to *Pythium* root rot is an acquired condition, apparently resulting from the absorption of soluble substances. Root rot was induced in soils in which Lahaina grows without marked root rot by amendments of sodium nitrate or cane compost. Under the theory of acquired susceptibility the aetiology of cane root rot in which *Pythium aphanidermatum* is the active agent was inferred to be as follows:

(1) Predisposition of cane varieties in diverse degree, associated with (2) nutritional or absorptive idiosyncrasies, such as sensitiveness to organic residues leading in certain varieties to (3) susceptibility to *Pythium aphanidermatum*.

It was at first thought that possibly cane residues bore a specific relation to induced susceptibility. That such is not the case was evidenced by the result from the preliminary experiment with sodium nitrate, where susceptibility apparently was induced. This indication that cane residues are not specific is now confirmed

* *Hawaiian Planters' Record*, Vol. XXXII, pp. 461-474, October, 1928.

Fig. 1. Lahaina roots. No. 1. In compost alone. No root rot. No. 2. In compost 50 per cent, Makiki soil 50 per cent by volume. Serious rotting of roots. No. 5. In Makiki soil alone. No root rot.

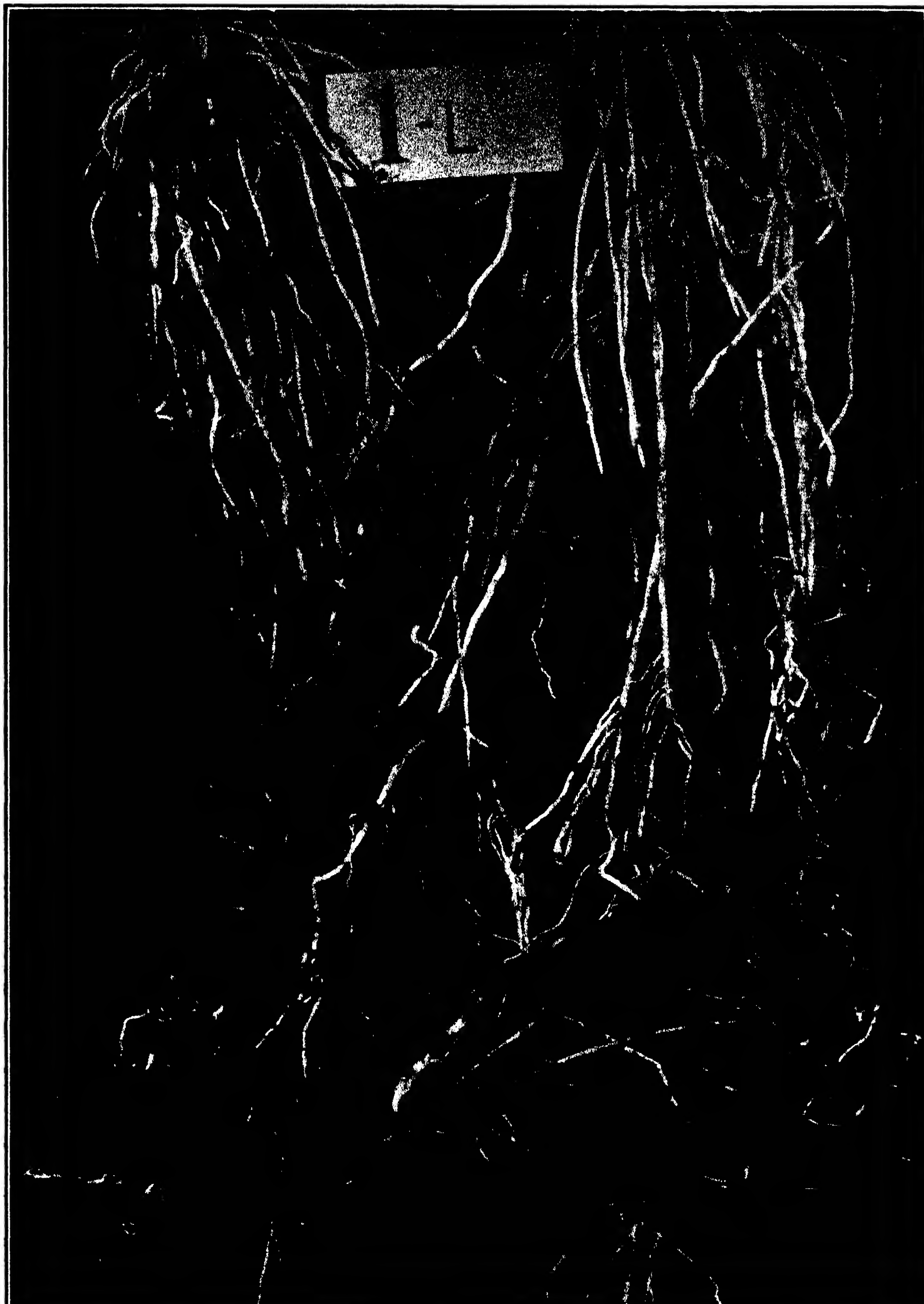


Fig. 2. Larger view of Lahaina roots of No. 1, Fig. 1, compost alone.

by evidence from experiments with stable manure. Thus far *Pythium* root rot of Lahaina cane has been induced in soils where it does not ordinarily occur, by the following treatments: (1) Excessive applications of sodium nitrate (soil from pathology plot). (2) With cane compost 25 per cent and 50 per cent by volume in virgin soil (Pawaa, Honolulu); in 50 per cent Makiki soil, 50 per cent compost; in 20 per cent, 25 per cent, and 40 per cent compost by volume respectively in pathology plot soil (12-inch pots in the open). (3) With stable manure in pathology plot soil, in 12-inch pots, by amendments of 5, 10, 15, 20, 25, 30, 40 and 50 per cent by volume. (4) In healthy Makiki soil by amendments of "molashcake" * at the rate of 3, 10, 15 per cent by weight. In "sick" Waipio soil root rot was greatly increased by "molashcake" amendments of 3 per cent by weight.

With cane compost in Makiki soil, Lahaina had a badly rotted root system in a half and half mixture, with healthy root mass in soil alone and in compost alone (Fig. 1). On the other hand, H 109 had healthy roots in Makiki soil, in the half and half mixture, and in pure compost (Fig. 4). H 109 is now under test in soil amended with stable manure.

The root rot resistant H 109 wherever tried in these experiments remains almost entirely free of root rot under the conditions where Lahaina suffers badly, corresponding to field observations. In pathology plot soil no significant root rot of H 109 occurred where amendments of compost were present in the following percentages by volume: 20, 25, 30, 50, 75 and 90. Like Lahaina it grows with mere traces of root rot in compost alone. Excessive applications of sodium nitrate and ammonium sulphate have not been observed definitely to alter the resistance of H 109 in soil from Waipio.

In some Kailua soil, from a locality where Lahaina has since grown with pale color as from lack of nitrogen, only traces of root rot developed in root study box cultures of Lahaina amended with 20 per cent and 40 per cent of cane compost. This is in contrast with three experiments, one with Makiki soil, one with virgin soil, and one with pathology plot soil. It is inferred that the total amount of nitrogen present is the important factor, not the amount of compost, manure, etc. The amounts of the latter are possibly significant to root rot in their relation to water-holding capacity, and other physical effects.

Experiment 101

Lahaina and H 109 in "Healthy" Soils Amended With Cane Compost: At the pathology plot sufficient soil for 56 twelve-inch pots was gathered and thoroughly mixed. Eight pots were filled with the soil, four for Lahaina controls and four for H 109 controls. In groups of four or eight the remaining 48 pots were filled with soil plus cane compost in percentages by volume as mentioned below. In the lower ranges (5 per cent to 15 per cent) only Lahaina was planted;

* "Molashcake" used was composed by weight as follows:

Mud press cake	33.8%
Bagasse	12.2%
Mill ash	5.5%
Molasses	48.5%
	100.0%

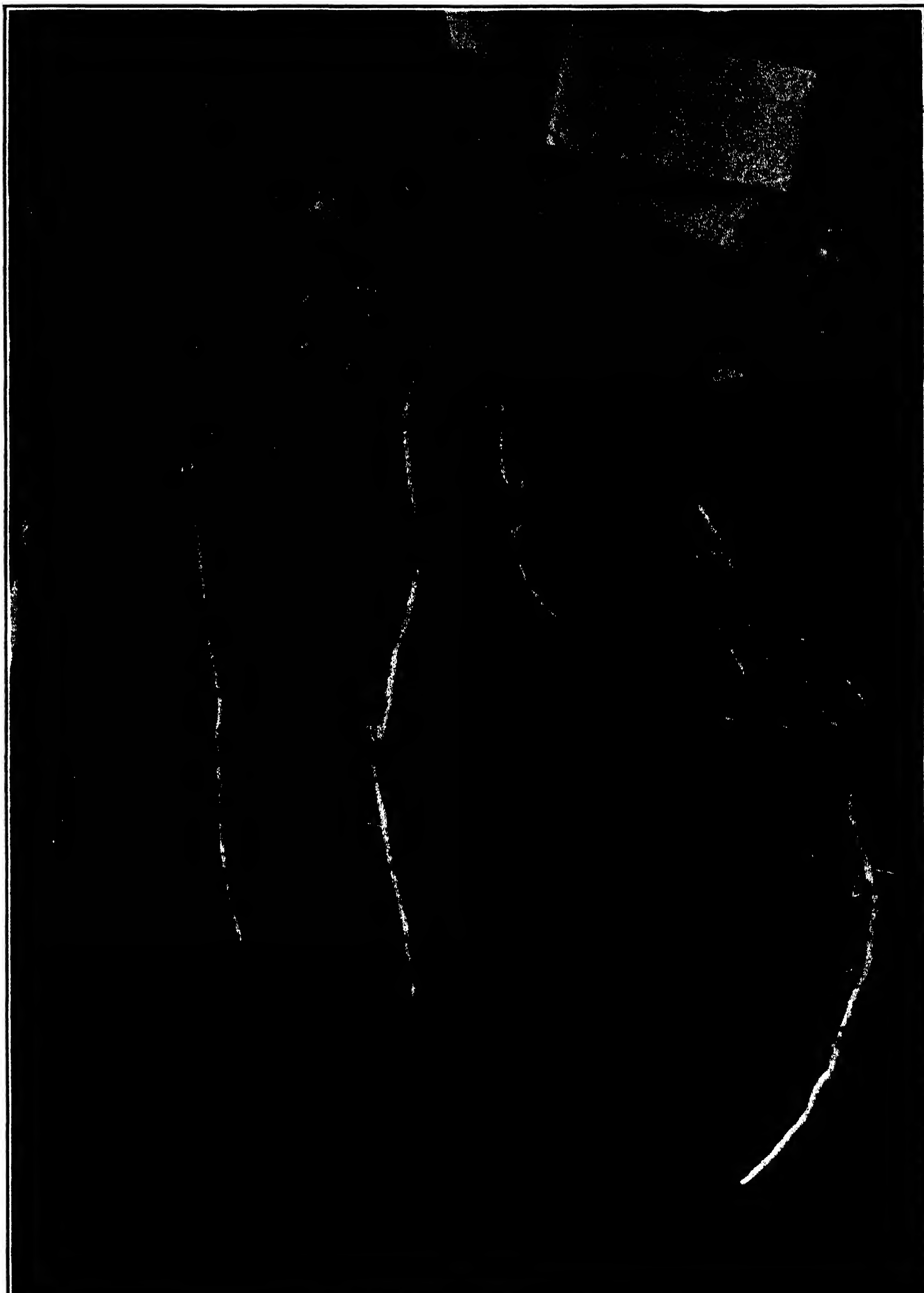


Fig. 3. Larger view of badly rotted roots of Lahaina plant No. 2, Fig. 1, in half compost, half soil, by volume.

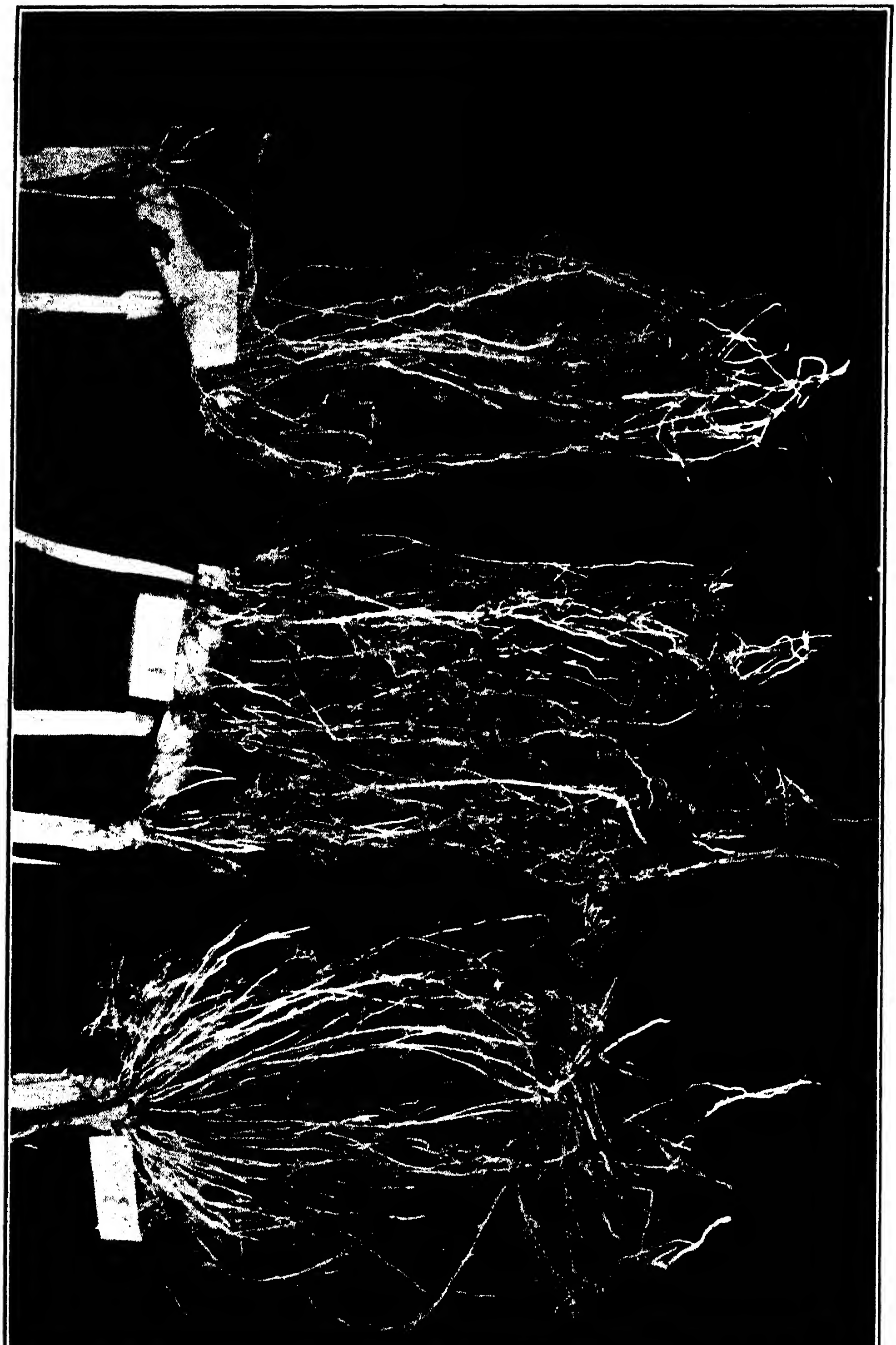


Fig. 4. H 109 roots. No root rot. (Compare with Fig. 1.) No. 3. In compost alone. No. 4. In compost 50 per cent, **Makiki soil** 50 per cent by volume. No. 6. **In Makiki soil** alone.

in the middle range (20 per cent to 40 per cent) four pots were planted with Lahaina and four with H 109, and in the upper range (50 per cent to 90 per cent) only H 109 was planted. The pots were placed in the open. The seed was obtained at Kailua, from vigorous cane of the varieties mentioned.

Three months after planting, the roots of one plant of each series were washed out. No root rot was found in the H 109. With Lahaina a trace occurred in the control and also in the 15 per cent compost mixture. Slight root rot was evident in the 5 per cent mixture, moderate in the 10 per cent mixture, and extreme in the 20 per cent mixture; moderate again in the 25 per cent mixture, with very bad rot in the 40 per cent mixture. Compare roots of control No. 1 with No. 21, grown in 20 per cent compost, in Figs. 5 and 6.

Another series was washed out fifteen days later, with similar results. The remaining units of each treatment and controls were washed out after a growing period of five months. With Lahaina cane in the lower ranges of compost amendment there was some improvement noted in root condition in the later observations, possibly due to a lowered concentration of the harmful material as a result of leaching and absorption by the plants. There was no improvement of Lahaina roots in the mixture of 40 per cent compost.

It is significant that there was no evidence of any weakening of the resistance of the H 109 in the used range of compost amendments.

Experiment 102

Lahaina in "Healthy" Soil Amended With Stable Manure: Pathology plot soil sufficient for 34 twelve-inch pots was thoroughly mixed. Lahaina grows well in such soil with very little evidence of root rot. Six pots were filled for controls. In groups of four stable manure was added to the other pots to make the following approximate percentages by volume: 5, 10, 20, 30, 40, 50 and 60. The pots were planted with Lahaina seed from Kailua, and placed in the open.

Three months after planting, the roots of one plant of each series were washed. A trace of root rot was detected in the control in two roots. With the 5-40 per cent manure amendments, the root systems were very badly rotted, the total root mass, however, varying considerably. With the 50 per cent manure amendment, the root system was distinctly better again, rot apparently not progressing as readily, though evidenced by numerous small red lesions. In the soil with 60 per cent amendment, the root mass was the largest of any of the entire series not excepting the control, but the roots were covered with red spots of incipient *Pythium* injury and possible burns from the manure. Root rot was not progressive. There were very few flaccid roots, much less than in the 50 per cent manure mixture.

Compare root systems of No. 1 control with Nos. 7 and 23 in Figs. 7 and 8. Root rot was present strikingly in all except the control and No. 31.

Another series was washed eighteen days later, with the same results. A very few flaccid roots were observed in the controls, while in the treated series nearly all roots were very badly rotted.

The remaining units of all series and controls were washed after a growing period of five months. The checks showed either no root rot or a negligible num-

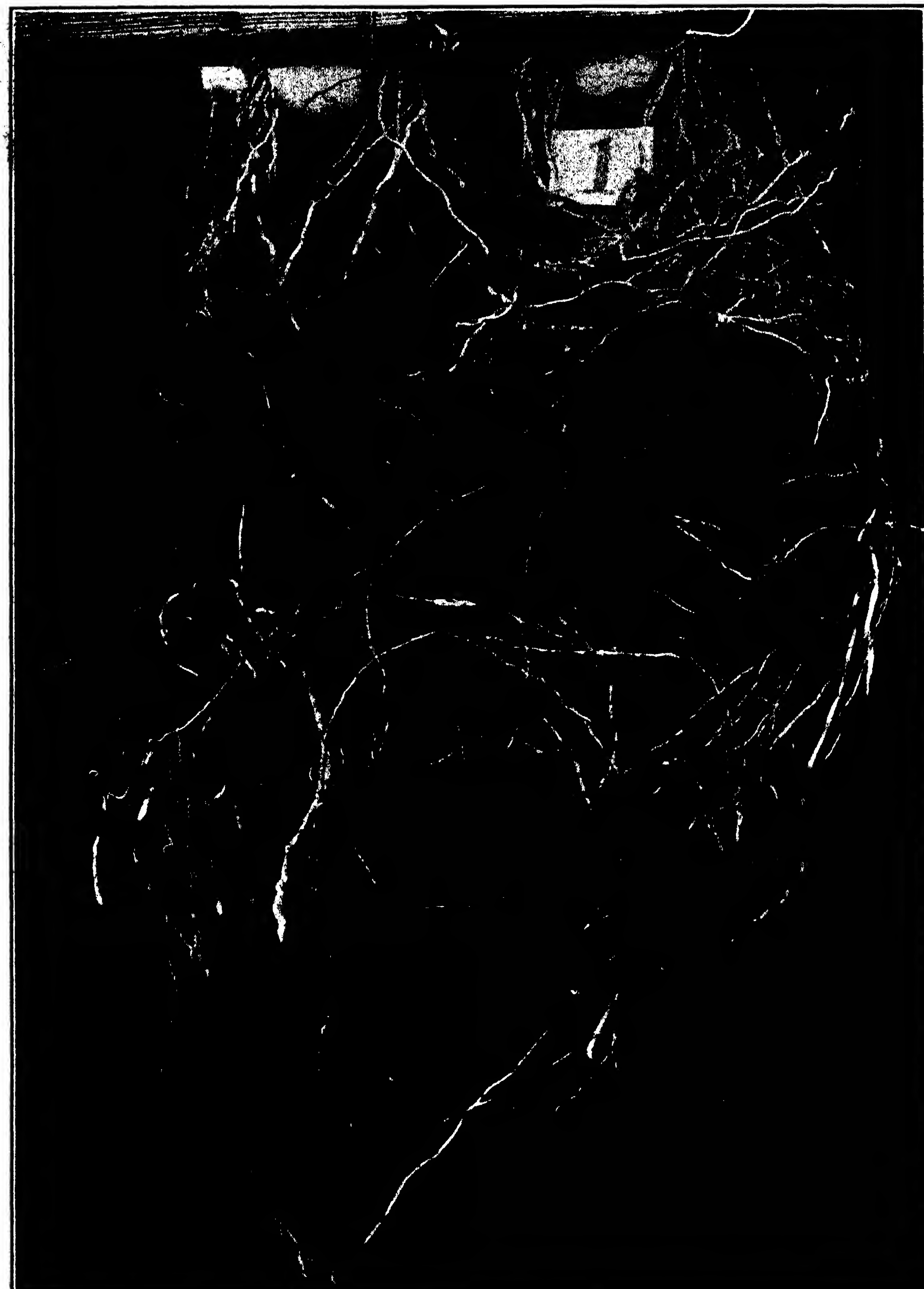


Fig. 5. Healthy roots of Lahaina grown in Makiki soil. (Compare with Fig. 6.)

Fig. 6. Badly rotted roots of Lahaina in Makiki soil amended with 20 per cent by volume of cane compost. (Compare with Fig. 5.)

ber of flaccid roots in the bottom of the pots. In the 5 per cent amendment the root system was considerably damaged by root rot, with progressively more in the 10 per cent and extreme root rot in the 20 to 60 per cent amendments.

As in the experiment with cane compost, at the end of the longer growing period there was evidence of improved conditions in the lower concentrations.

"Molashcake" Experiment With Waipio Soil

Lahaina "sick" Waipio soil from Field E sufficient for 16 twelve-inch pots was thoroughly mixed June 13, 1928. This soil was air dried. Four pots were filled for controls. Four pots were filled with soil, each lot being mixed with one pound of "molashcake"; four with 3 pounds of "molashcake" each; and four with 5 pounds of "molashcake." The pots were kept moist for three months to allow the molasses to ferment, and planted August 9, with healthy top Lahaina seed from Kailua.

The object of the experiment was to learn if there was any improvement in the Lahaina roots as compared with the natural "sick" soil. It was thought that if there was too much nitrogeneous matter in the sick soil denitrification might ameliorate the condition. The reverse was true, the root rot was greatly aggravated, so that apparently denitrification did not materially reduce the soil content of nitrogen, but there was rather an increase of available nitrogen, if this is the deleterious factor.

There was no apparent benefit to aerial growth from the "molashcake" noted during the experiment; the plants with 3 pounds of "molashcake" were always dry appearing and somewhat stunted, while those with 5 pounds were very poor, stunted, with dried leaves, and were about dead by November 21.

The root systems of one unit of each series were washed out at that time, and photographed (Fig. 9). In the natural sick soil there was moderate root rot in evidence, the root mass being fair (Figs. 9 and 10, No. 1). In the pot with one pound of "molashcake," (approximately 3 per cent, by weight), rotting was prevalent, the older roots being mostly rotted, with conspicuous rotting of younger roots in evidence (Fig. 9, No. 5). With 3 pounds of "molashcake" (approximately 10 per cent by weight) new roots were rotting badly, and the old roots had all rotted off (Figs. 9 and 10, No. 10). With 5 pounds of "molashcake" (approximately 15 per cent by weight) scarcely any roots were present, these few roots badly attacked and flaccid (Fig. 9, No. 13). This was typical *Pythium* root rot with abundant evidence of the fungus *Pythium aphanidermatum*.

Another series was washed December 3, and the remaining units December 18, with similar results.

"Molashcake" Amendments in Makiki Soil

A parallel experiment was conducted, substituting "healthy" Makiki soil for the "sick" Waipio soil. The results were comparable at the higher concentrations but with one pound of "molashcake" there was improved top growth over the controls, and in general less root rot in this normally healthy soil amended with "molashcake" than with corresponding amendments in the Waipio "sick" soil.

Fig. 7. Healthy roots of Lahaina in Makiki soil, No. 1, and badly rotted roots of Lahaina in similar soil amended with 5 per cent by volume of stable manure (No. 7).

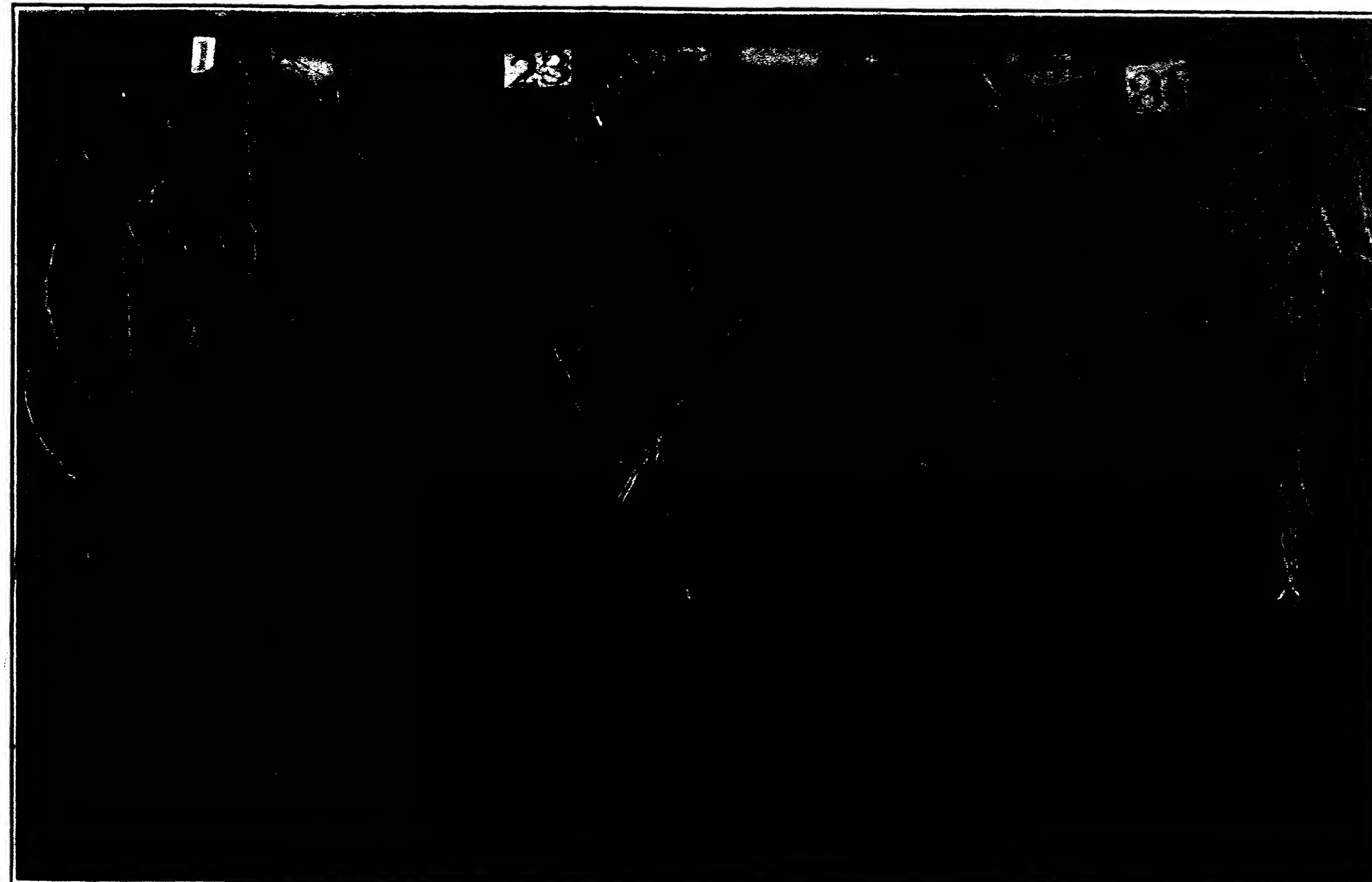


Fig. 8. Roots of No. 1 control grown in Makiki soil; of No. 23, soil amended with 40 per cent by volume of stable manure (serious rotting); and of No. 31, stable manure 60 per cent.

Fig. 9. Roots of Lahaina in Waipio sick soil. Rot was greatly increased by "molasheake." No. 1. Control. No. 5. Soil plus one pound "molasheake" (3 per cent by weight.) No. 10. Three pounds "molasheake" (10 per cent). No. 13. Five pounds "molasheake" (15 per cent).

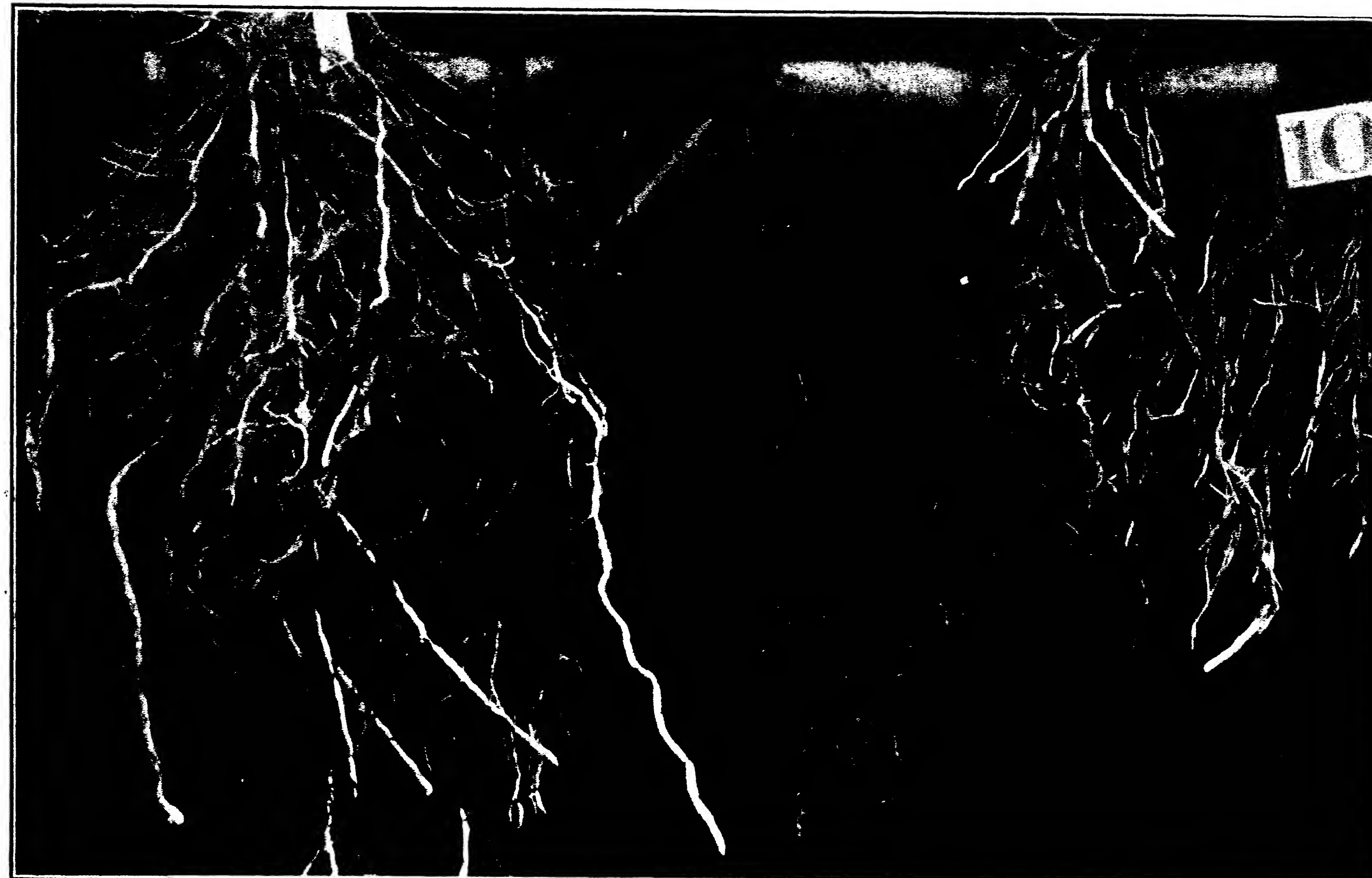


Fig. 10. Larger view of No. 1 control and No. 10, in "molasheake" 10 per cent by weight, shown in Fig. 9. In general, photographs show only relative root masses, and indicate little as to degree of root rot.

SUMMARY

1. Previous experiments demonstrated that *Pythium* root rot of Lahaina cane was induced in virgin soil or healthy soils by amending with cane compost or excesses of sodium nitrate.

2. Healthy soil was amended with stable manure to determine if cane residues were specific in inducing root susceptibility, or if other organic matter rich in nitrogen would act similarly. Much less stable manure was required than of cane compost to induce root rot in healthy Makiki soil.

3. H 109 was grown in various percentages of cane compost in soil to learn if it became susceptible to root rot. With concentrations of 20, 25, 40, 50, 70 and 90 per cent of compost by volume in pathology plot soil, no appreciable root rot of H 109 occurred. H 109 grew luxuriantly also in compost alone, as did Lahaina, without root rot. Lahaina developed serious root rot in 50 per cent compost, 50 per cent Makiki soil, while H 109 in contrast, had a healthy root system.

4. It was thought that molasses amendment with possible denitrification resulting might ameliorate the condition if excesses of nitrogen for Lahaina cane were present in Waipio soil. "Molashcake," fermented in Waipio soil, greatly aggravated root rot of Lahaina subsequently planted. "Molashcake" similarly fermented in healthy Makiki soil, induced serious root rot. The latter is not ordinarily conspicuous in this soil. If excessive nitrogen is the deleterious factor, "molashcake" serves to greatly increase it.

Studies of the Interaction Between Fertilizers and Soils

By Guy R. Stewart

Introduction

In considering the action of a fertilizer and its value in giving an adequate increase in crop yield it is customary to figure the probable effect of the fertilizer in terms of the amounts of the so-called plant food, that is, nitrogen, phosphoric acid and potash, contained in the material. This is unquestionably a sound way to compare the relative commercial value of two different mixtures. It is, however, only a part of the entire story that should be considered in studying its effect on the soil. There is first of all the question of the availability of the plant nutrients present in any such mixture. Previous laboratory studies carried on by McGeorge (2) at this Station would indicate that the cane plant probably absorbs nitrogen most readily when the nitrogen is in the nitrate form. This means that the organic and ammoniacal forms of nitrogen will have to undergo conversion to nitrates before the nitrogen will be most easily taken up by the cane plant.

It is generally believed that similar changes have to take place in the solubility of phosphates before the plant can absorb this important nutrient. Both Truog (6) and Parker (4) have indicated, however, that it is not impossible that phos-

phate can be absorbed through the root hairs without it being necessary for the phosphate to actually become soluble.

In addition to the question of the availability of the nutrients, every soluble salt will have some influence in either increasing or decreasing the solubility of the partly weathered soil minerals. This is equally true of neutral salts and of those which leave an acid residue, though the solubility effect may be greater in the case of the physiologically acid salts such as ammonium sulfate.

It has been previously pointed out by Hance (1) and the writer (5) that every soluble salt tends to change the relationship of the replaceable bases present in the soil. These replaceable bases are held in combination with the soil colloid. The addition of either the sodium radical of nitrate of soda or the ammonium radical of ammonium sulfate to a soil, will result in the replacement of a portion of the bases which were previously combined with the soil colloid. In most soils the base which will be replaced in greatest amount will be calcium. Where a soil is loose and open in texture without a great amount of colloids the replaced calcium may be carried out of the soil in the drainage water. The greater number of our island soils contain sufficient colloids so that the replaced calcium will not be washed out rapidly. In this case the calcium may be taken up again, by the soil colloid. This will be especially true if there is an adequate calcium reserve present in the soil. It may thus be seen that the condition of the replaceable bases in the soil will be subject to constant change following the application of fertilizers.

Numerous studies have shown, also, that all fertilizer applications tend to affect the biological life of the soil. Phosphates have a notable stimulating effect on the growth and development of the soil bacteria which change ammonia over to nitrites and nitrates. The addition of nitrogen compounds increases the activity of the organisms which decompose cellulose and carbohydrates in the soil. It may therefore be seen that the secondary effect of a fertilizer is an important factor to be considered in estimating the final value of such a soil amendment.

Experimental

The studies recorded here were undertaken in order to try to give some information as to the relative value of raw rock phosphate and superphosphate, when applied to acid and neutral soils. One of the soils chosen for the study was a decidedly acid clay soil from Field 40 of the Hanamaulu section of Lihue plantation. This soil is low in lime content and is also appreciably lacking in available phosphates and potash. The second soil used in the investigation was a red clay loam from Field 39, Oahu Sugar Company. This soil is neutral in reaction. It contains a moderate amount of available potash and a fairly good supply of available phosphate. The reserve content of total phosphates is rather low, however, and similar soils with this low reserve supply have shown a response to phosphate fertilization. The composition of the two soils is as follows:

Chemical Composition of Soils

Field	Location	Soil Reaction	Citric Acid Soluble Silica SiO_2 %	Citric Acid Soluble Lime CaO %	Citric Acid Soluble Potash K_2O %	Citric Acid Soluble Phosphate P_2O_5 %	Strong HCl Soluble Lime CaO %	Strong HCl Soluble Potash K_2O %	Strong HCl Soluble Phosphate P_2O_5 %	Total Potash K_2O %	Total Phosphate P_2O_5 %
40	Hanamaulu Sec. Lihue	5.0	0.02	0.06	0.010	0.0026	0.15	0.42	0.15	0.63	0.47
39	Oahu Sugar Co.	7.3	0.16	0.24	0.045	0.0118	0.40	0.60	0.20	1.12	0.25

Three fertilizer mixtures containing small amounts of nitrogen and large percentages of potash and phosphate were applied to a series of duplicate 5-gallon stoneware crocks containing 40 pounds of each soil.

Fertilizer mixtures

Fertilizer 1 – 2% Total nitrogen { 1.5% nitrate nitrogen; .5% organic nitrogen }

13.5% P_2O_5 { 10.5% P_2O_5 from superphosphate; 3.0% P_2O_5 from bone meal }

12.5% K_2O derived from sulphate and nitrate

Fertilizer 2— 2% Total nitrogen { 1.5% from ammonium sulfate; .5% organic nitrogen }

18.25% P_2O_5 { 15.25% P_2O_5 from raw rock; 3.0% P_2O_5 from bone meal }

17.0% K_2O from sulphate of potash

Fertilizer 3— 2% Total nitrogen { 1.5% from ammonium sulfate; .5% organic nitrogen }

19.75% P_2O_5 { 16.75% P_2O_5 from raw rock; 3.0% P_2O_5 from bone meal }

18.5% K_2O from muriate of potash

In the case of the acid soil from Lihue plantation the mixtures were put on at the rate of 1500 pounds per acre foot of surface soil. Upon the neutral soil from Oahu Sugar Company, the mixtures were applied at the rate of 800 pounds per acre foot of surface soil. Distilled water was added to bring each soil up to an approximately optimum moisture content. Further additions of distilled water were made at one or two-week intervals, throughout the period of the study, in order to maintain a uniform percentage of moisture in the soils.

Three days after the first application of fertilizer, the displaced soil solution was obtained from a jar of each treated soil and from an untreated jar of blank soil. The displaced soil solution was obtained by Parker's (3) modification of Ischerekov's alcohol displacement method. It was hoped that this displaced soil solution would show the changes occurring in the more important soil nutrients as the result of the fertilizer treatments.

Thirty days after the application of the fertilizer mixtures, the soil solutions were displaced from a second series of jars. This was to determine the development of soluble nutrients which would occur in the time which commonly elapses in the field before nitrogen salts are put on. At the same time nitrogen was applied to additional jars which had already stood thirty days. Half the jars were treated with nitrogen in the form of nitrate of soda and the other half with nitrogen derived from ammonium sulfate. Upon the acid soil the nitrogen application

was at the rate of 175 pounds nitrogen per acre while upon the neutral soil, nitrogen was put on at the rate of 260 pounds per acre foot of surface soil.

Three days following the nitrogen applications, the soil solutions from a further series of jars were displaced and analyzed. Duplicate sets of jars of each soil were then allowed to stand for sixty days longer after the nitrogen treatments. The soil solutions were then displaced. The final set of jars included in the study were carried on for an additional sixty-day period and was then subjected to analysis in the same manner as the previous portions of the series.

It should be pointed out that the three fertilizer mixtures employed in this study supply all the major nutrients in different forms. In fertilizer 1, the greater portion of the small nitrogen content is derived from nitrate of potash or nitrate of soda. The major portion of the phosphate content is derived from superphosphate and the greater part of the potash is supplied by sulphate of potash.

In fertilizer 2, on the other hand, the larger part of the nitrogen is derived from ammonia sulfate. The larger part of the phosphate is furnished by raw rock. The potash is entirely derived from sulphate of potash.

The greater part of the nitrogen in fertilizer 3 is again supplied by ammonium sulphate. The greater part of the phosphate is furnished by raw rock, and all the potash is supplied by muriate of potash.

The analytical results of the various series are expressed in two different ways. Tables I to IV, inclusive, give the results in tabular form. It will be found easier, however, to follow the changes occurring in the more important nutrients as a result of the treatments, in the graphical representation of the analytical results given in Figs. 1 to 4. The graphs will now be considered individually.

Soil Reaction

In this graph (Fig. 1) the reaction of the two untreated soils is seen to show a moderate degree of fluctuation. The addition of nitrate of soda to the acid soil caused at first a slight increase in alkalinity. This alkalinity later disappeared and the final reaction was slightly more acid than the untreated soil. With the neutral soil, nitrate of soda caused a slight decrease in alkalinity. In the case of ammonium sulfate there was a very slight increase in the acidity of the acid soil. This acidity persisted and in fact increased towards the latter part of the experiment. On the neutral soil, the ammonium sulfate caused an appreciable increase in acidity three days after this fertilizer had been applied. The difference in soil reaction between the untreated soil and that which had received ammonium sulfate, became smaller as time went on. The indications are that eventually these two neutral soils would have had the same final reaction.

The application of the three fertilizer mixtures to the acid soil caused a slight but consistent increase in alkalinity. This increase in alkalinity also occurred on the neutral soil. The greatest change was shown with fertilizer 2.

The application of nitrate of soda caused the reaction to return to approximately the same figure as was originally found in practically all treatments of both the acid and the neutral soils.

The addition of ammonium sulfate to the acid soil, caused a gradual development of acidity, with each of the three fertilizer mixtures. The action of am-

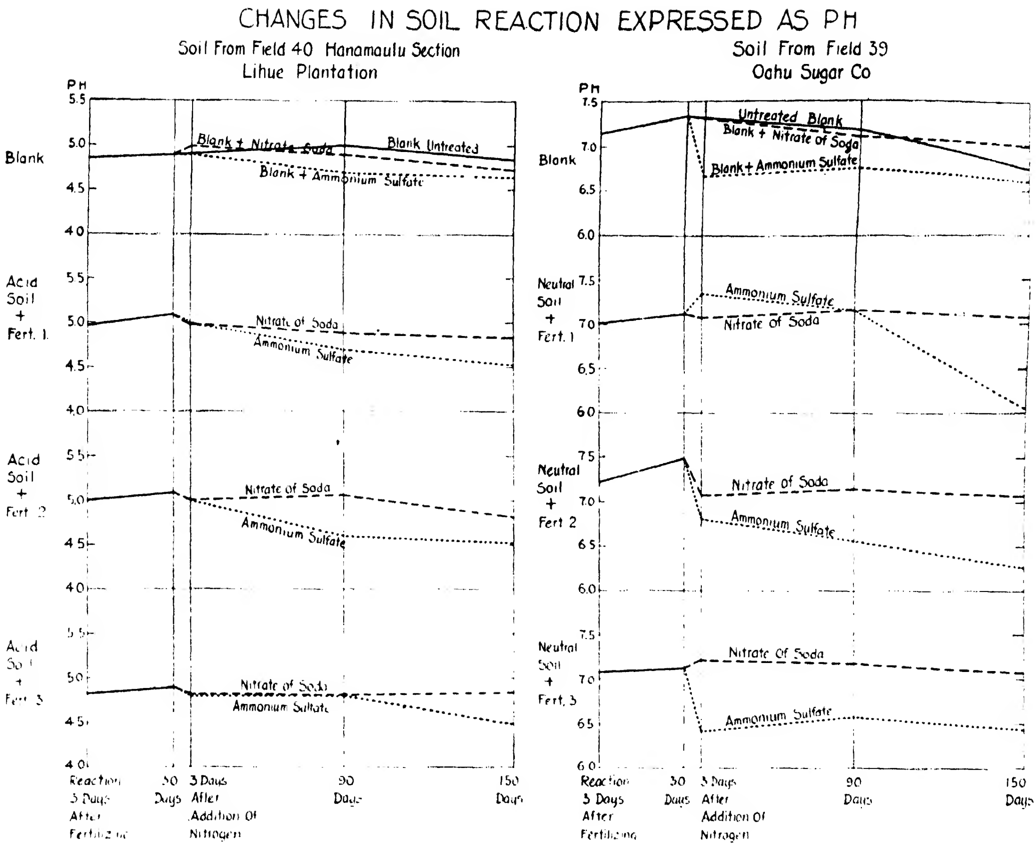

CHANGES IN SOIL REACTION EXPRESSED AS PH
Soil From Field 40 Hanamaulu Section
Lihue Plantation
Soil From Field 39
Oahu Sugar Co
Blank
Acid Soil + Fert. 1
Acid Soil + Fert. 2
Acid Soil + Fert. 3
Neutral Soil + Fert. 1
Neutral Soil + Fert. 2
Neutral Soil + Fert. 3
Blank + Nitrate Soda
Blank Untreated
Blank + Ammonium Sulfate
Untreated Blank
Blank + Nitrate of Soda
Nitrate of Soda
Ammonium Sulfate
Reaction 5 Days After Fertilizing
30 Days
3 Days After Addition Of Nitrogen
90 Days
150 Days

Fig. 1

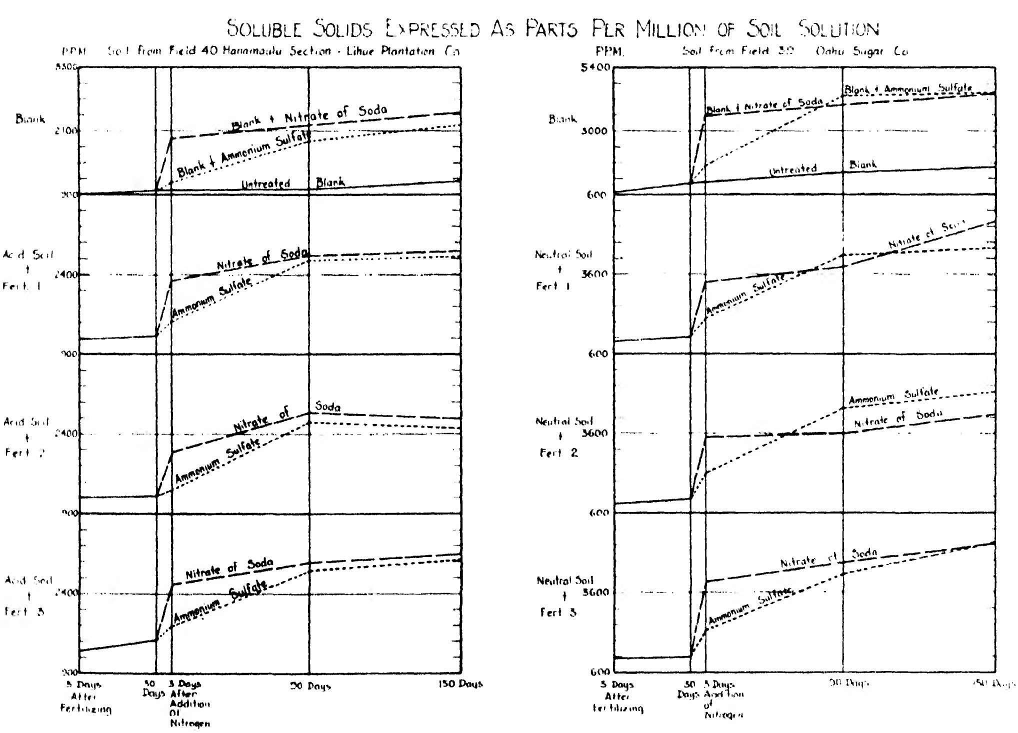

SOLUBLE SOLIDS EXPRESSED AS PARTS PER MILLION OF SOIL SOLUTION
Soil From Field 40 Hanamaulu Section - Lihue Plantation Co
Soil From Field 39 Oahu Sugar Co
PPM
Blank
Acid Soil + Fert. 1
Acid Soil + Fert. 2
Acid Soil + Fert. 3
Neutral Soil + Fert. 1
Neutral Soil + Fert. 2
Neutral Soil + Fert. 3
Blank + Nitrate of Soda
Blank + Ammonium Sulfate
Untreated Blank
Nitrate of Soda
Ammonium Sulfate
5 Days After Fertilizing
30 Days
3 Days After Addition Of Nitrogen
90 Days
150 Days

Fig. 2

monium sulfate, upon the neutral soil, showed considerable variation, depending on the fertilizer which had been added. In the case of fertilizer 1, the first effect of ammonium sulfate was to cause a slight development of alkalinity, followed by the gradual development of an acid reaction. With fertilizer 2, there was an immediate development of acidity, which tended to increase as time went on. Fertilizer 3, caused an immediate increase in acidity, followed by a slight decrease in acid reaction.

Changes In Total Solids

The effect of the various treatments upon the development of soluble solids is shown to be a remarkably consistent influence tending towards increasing the materials in solution (Fig. 2). Both untreated soils showed a gradual development of soluble materials in the soil solution. The influence of the three fertilizers in the first thirty-day period towards increasing the total solids was not large. The addition of both nitrate of soda and ammonium sulfate caused a rapid increase in the soluble material present in the soil solutions. The immediate effect was greatest with nitrate of soda. The solubility effect of the ammonium sulfate steadily increased in the acid soil, but had not quite equalled the nitrate of soda at the close of the experiment. With the neutral soil, the ammonium sulfate had, in the case of fertilizers 2 and 3, increased the soluble solids to an amount that was equal to, or greater than, nitrate of soda by the time the last series of analyses was made.

Nitrate Nitrogen

The development of nitrate nitrogen in the several treatments is seen to be notably influenced by the acidity of the soil and the lime reserve present in it (Fig. 3). In the acid soil with a low lime content, the amount of nitrates was at all times larger where nitrate of soda was applied than where ammonium sulfate was used. At the close of the experiment none of the treatments with ammonium sulfate on the acid soil had developed as much nitrate nitrogen as was present from the addition of nitrate of soda. With the neutral soil the nitrification of ammonia was both more rapid and complete than on acid land. With fertilizers 2 and 3 the ammonium sulfate furnished an amount of nitrate nitrogen equal to the nitrate of soda. The nitrate development was practically equally good with fertilizer 1, but was not so good where no fertilizer was applied.

Soluble Lime

The effect of the fertilizer mixtures upon the development of soluble lime was small, but caused a consistent increase, in the first thirty days before nitrogen salts were applied (Fig. 4). The immediate effect of nitrate of soda was greater than that of ammonium sulfate. Both salts only caused a slight change in the lime control of the soil solution of the acid soil, but caused an immediate increase in the soluble lime of the neutral soil. Upon both the acid and neutral soil ammonium sulfate eventually brought the largest amounts of lime into solution, irrespective of fertilizer treatment.

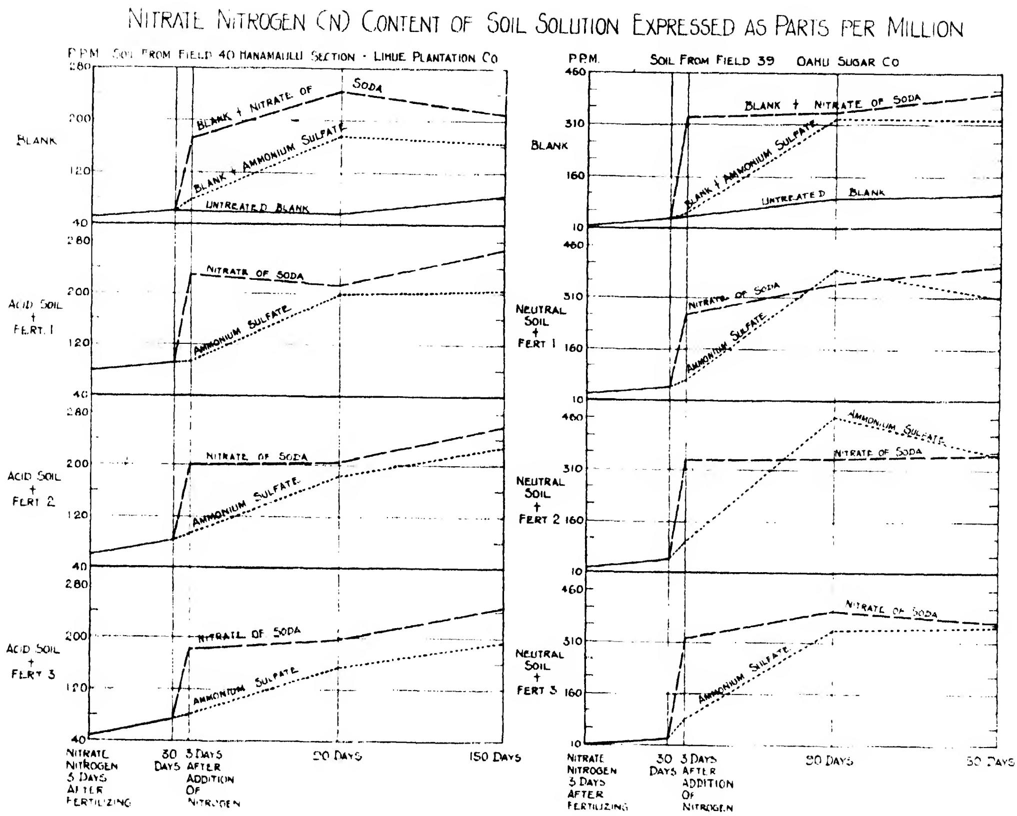

NITRATE NITROGEN (N) CONTENT OF SOIL SOLUTION EXPRESSED AS PARTS PER MILLION
SOIL FROM FIELD 40 HANAMAULU SECTION · LIHUE PLANTATION CO
SOIL FROM FIELD 39 OAHU SUGAR CO
BLANK + NITRATE OF SODA
BLANK + AMMONIUM SULFATE
UNTREATED BLANK
NITRATE OF SODA
AMMONIUM SULFATE
30 DAYS
3 DAYS AFTER ADDITION OF NITROGEN
90 DAYS
150 DAYS

Fig. 3

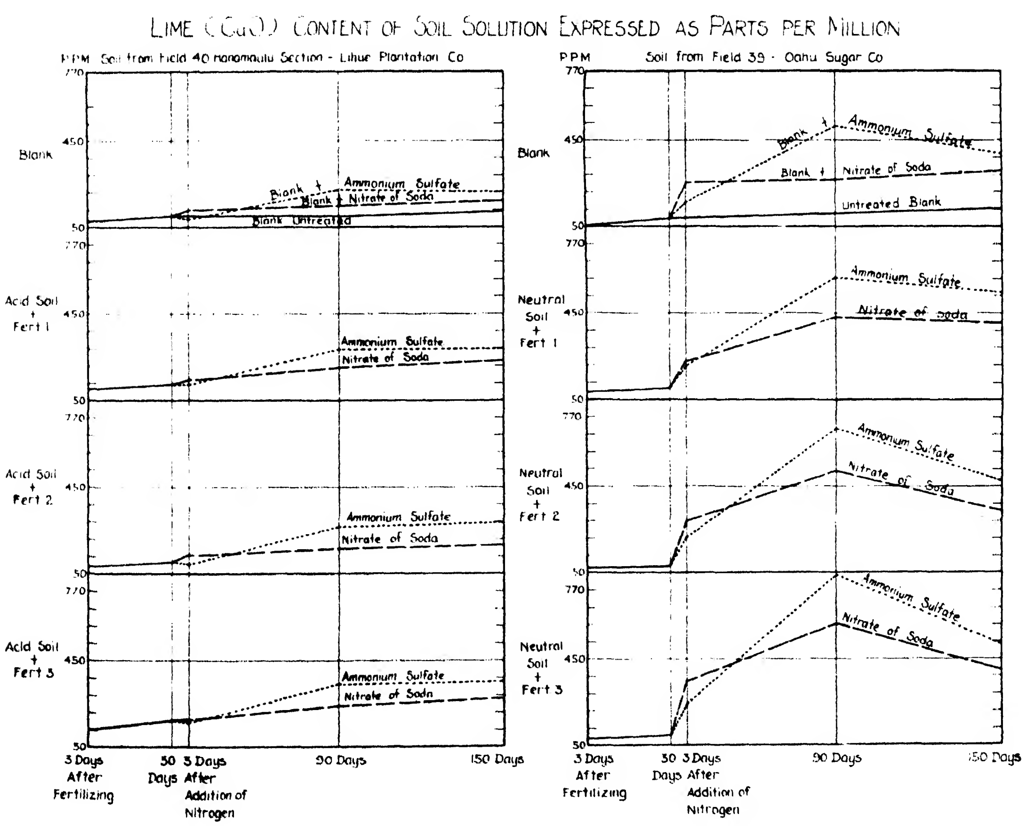

LIME (CaO) CONTENT OF SOIL SOLUTION EXPRESSED AS PARTS PER MILLION
Soil from Field 40 Hanamaulu Section - Lihue Plantation Co
Soil from Field 39 · Oahu Sugar Co
Blank + Ammonium Sulfate
Blank + Nitrate of Soda
Untreated Blank
Ammonium Sulfate
Nitrate of Soda
3 Days After Fertilizing
30 Days
3 Days After Addition of Nitrogen
90 Days
150 Days

Fig. 4

Soluble Phospahte

The determination of soluble phosphates recorded in Fig. 5 clearly proves the remarkably strong fixing power of both the acid and neutral Hawaiian soils for phosphates. The first determination of phosphates made three days after the application of the fertilizer mixtures to the soil, showed only a significant increase in the phosphate content in one case. This was where fertilizer 1, containing superphosphate had been applied to the acid soil. When the next series of analyses were made thirty days later, none of the jars showed a significantly higher content of soluble phosphates than were present in the untreated soil. The application of both nitrate of soda and ammonium sulfate caused the development of an increased amount of soluble phosphate, in the acid soil, within three days' time. With the neutral soil there was little immediate effect. Later in the experiment there appears to be a definite development of soluble phosphates, resulting from the application of both nitrate of soda and ammonium sulfate to this neutral soil. There is one discordant determination upon the blank acid soil. This shows a large increase in the phosphate content of the untreated soil at the last period of sampling. There appears to be no explanation for this sudden increase, which decidedly destroys the consistency of the results obtained with this soil. With the neutral soil the figures show a consistent increase in the content of soluble phosphates resulting from the application of nitrate of soda and ammonium sulfate. There is no evidence in these studies of any difference in the effect of nitrogen salts upon the solubility of the phosphate, whether the source of the phosphate was superphosphate or raw rock phosphate.

In view of the possibility suggested by other workers, to which allusion has previously been made, that phosphates do not have to come into solution in order to be available to the plant, it will require further work before we can say whether these two forms of phosphate are of equal value for the cane crop.

It is therefore planned to continue these studies with further investigation of the changes taking place in phosphate-treated soils under field conditions. In these additional studies the composition of the cane crop grown upon the phosphate-treated and the control, untreated plots will also be determined at several stages of growth.

Solubility of Potash

The amount of potash in the soil solution of both the acid and neutral soils was materially increased by the addition of all three fertilizer mixtures (Fig. 6). Thirty days after the experiment started this solubility was slightly lower with all three fertilizers used on the acid soil and with fertilizer 2 upon the neutral soil. The addition of both ammonium sulfate and nitrate of soda caused an immediate increase in the content of soluble potash in the soil solution of both the fertilized and unfertilized soils. In general, the increase in soluble potash after nitrogen fertilization, was greater where the three fertilizers had been applied than upon the blank soil. Ammonium sulfate gave a slightly larger increase in soluble potash upon the acid soil, than did nitrate of soda. With the neutral soil, neither salt showed consistent superiority in the development of soluble potash in the soil solution.

PHOSPHORIC ACID (P_2O_5) CONTENT OF SOIL SOLUTION EXPRESSED AS PARTS PER MILLION

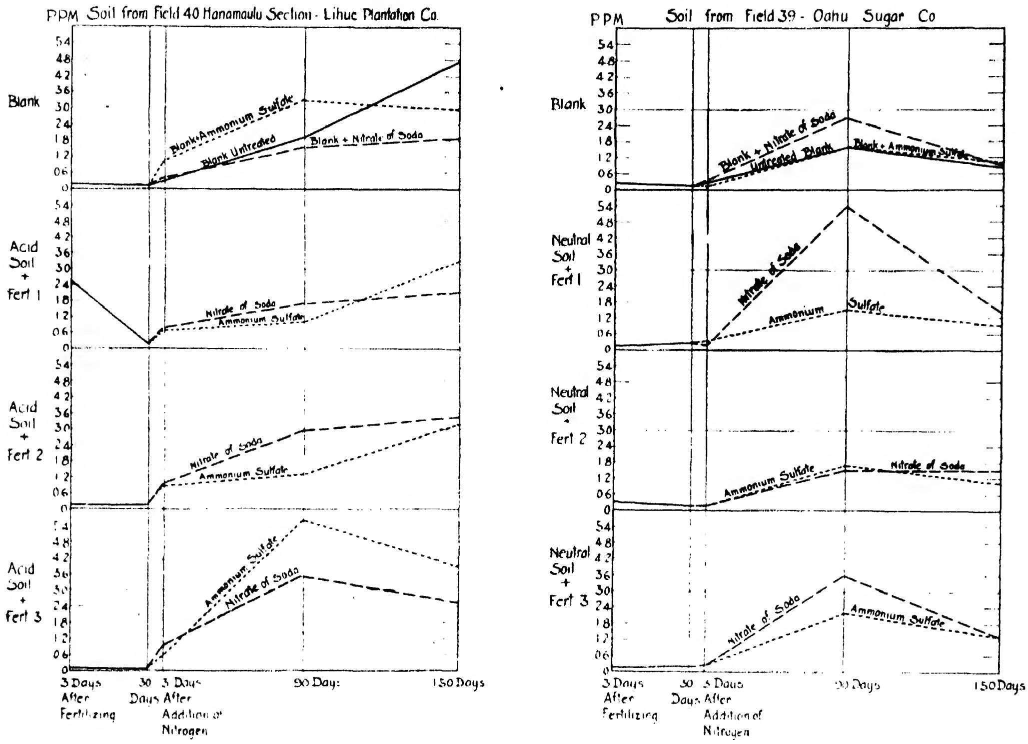


Fig. 5

Conclusions To Be Drawn From the Study

The above work appears to warrant the following general conclusions. The secondary effect of a fertilizer upon a soil is of fundamental importance in determining either the increase or decrease of soil acidity. This residual effect is a notable factor in bringing soluble materials into the soil solution and may conceivably increase plant growth through indirectly increasing the supply of soil nutrients.

In the experiments recorded here there was a development of soil acidity in both an acid and a neutral soil following the addition of nitrogen in the form of ammonium sulfate. This acidity tended to decrease where there was an adequate lime reserve in the soil. The addition of nitrate of soda to an acid and a neutral soil in each case caused a slight increase in soil alkalinity. This alkalinity later disappeared and the final reaction was practically the same as that of the untreated soil. An appreciable part of the effect of either mixed fertilizers or soluble nitrogenous salts upon the soil appears to consist in the development of increased amounts of soluble solids in the soil solution. These soluble solids consist of both inorganic salts and organic matter. The devolpment of soluble solids in the soil solution was increased to a greater extent in an acid soil by nitrate of soda than by ammonium sulfate. In a neutral soil, a greater amount of material became soluble immediately after nitrate of soda was applied. The development of soluble solids with ammonium sulfate was practically equal to nitrate of soda after several months had elapsed.

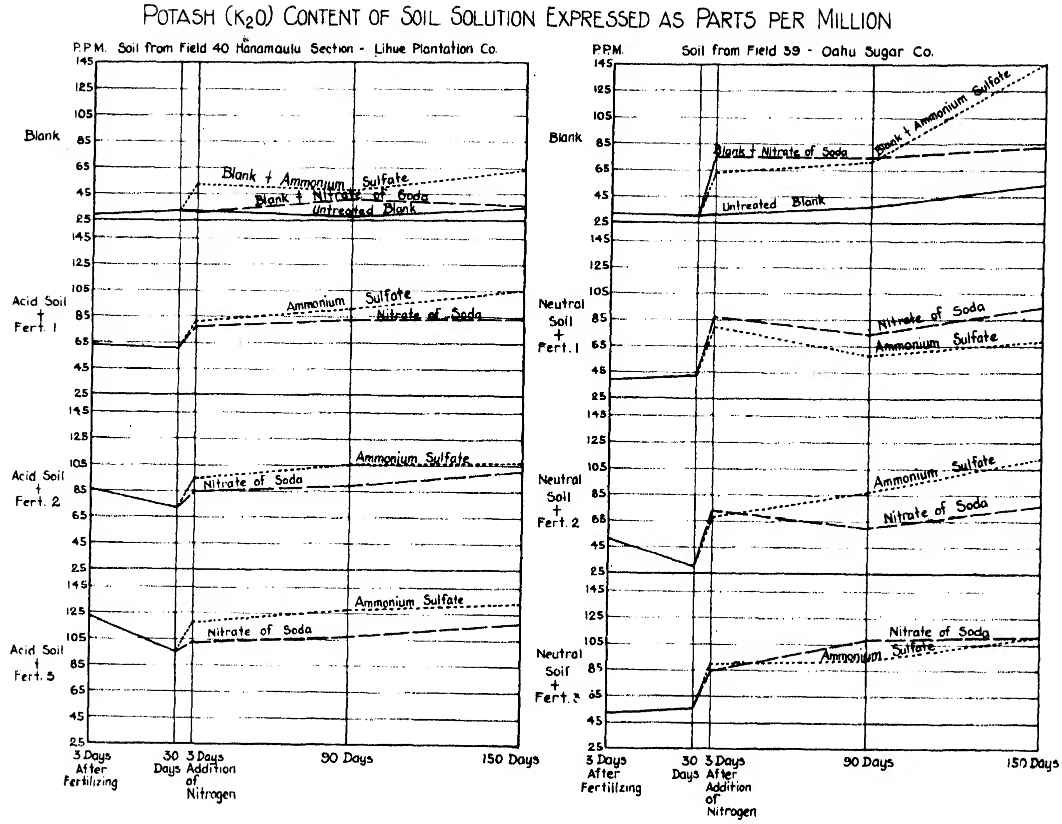


Fig. 6

The development of nitrate nitrogen, as has been previously pointed out, is largely determined by the reaction of the soil and the reserve lime that is present. In the case of the acid soil used in these studies, the cultures receiving nitrate of soda always contained more nitrates than those treated with ammonium sulfate. With the neutral soil the nitrate formed, after two months, from ammonium sulfate, was practically equal to that furnished by nitrate of soda.

The effect of mixed fertilizers, which consisted largely of phosphate and potash, upon the content of soluble lime in the soil solution was very slight. Moderate increases in soluble lime were caused by the three fertilizers used in this study. The addition of nitrate of soda and ammonium sulfate caused a definite increase in the soluble lime present in the soil solution.

The determination of the soluble phosphate present in the soil solution obtained in this study emphasizes the strong fixing power for phosphates which Hawaiian soils possess. The determination of phosphates made three days after superphosphate and raw rock phosphate were added to a neutral and acid soil only revealed a higher content of soluble phosphate in the case of one superphosphate treatment. There was a definite development of soluble phosphates caused by both nitrate of soda and ammonium sulfate. Owing to the high fixing power of the soils used, for phosphate compounds, no definite conclusions can be drawn as to the relative value of the two forms of phosphate upon these two soils. It is believed the results suggest that it may not be necessary that phosphates actually be soluble in the soil solution in order to be available for the cane plant.

The greatest development of soluble potash in the soil solution occurred after the addition of nitrate of soda or ammonium sulfate. The largest amount of potash was freed by these salts in soils which had received potash fertilizers.

Summary

1. The experiments carried on in this study were intended to show the relative availability of superphosphate and raw rock phosphate as a source of phosphate on an acid and a neutral soil.

2. The study was carried out on a laboratory scale with an acid soil from Lihue Plantation Company and a neutral soil from Oahu Sugar Company.

3. Three fertilizer mixtures containing small amounts of nitrogen and large amounts of phosphates and potash were added to each soil, in amounts comparable to those used in the field.

4. The displaced soil solutions were obtained three days after the first addition of the fertilizers. Duplicate jars were then analyzed thirty days later. At this thirty-day period nitrate of soda and ammonium sulfate were added to additional jars and the soil solutions were displaced three days later. Further sets of jars were allowed to stand for an additional period of sixty days and 120 days after the addition of the nitrogen salts.

5. The results of the study give valuable information as to the changes in soil reaction, development of soluble solids, nitrate formation, solubility of lime and the solubility of potash The figures obtained show the influence of nitrate of soda and ammonium sulfate upon the development of soluble phosphates. There is no clear proof of the relative value of superphosphate and raw rock phosphate. It is planned to continue this study in the field.

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TABLE I—INTERACTION OF FERTILIZER SALTS AND SOILS

Results Expressed as Parts per Million in Solution

Soil	Treatment	Reaction of Soil and Fertilizer Mixture	Soil Solutions Displaced 3 Days After Addition of Fertilizer							
			Total Solids	Volatile Solids	Non-Volatile Solids	Silica SiO_2	Nitrate Nitrogen	Calcium CaO	Phosphate P_2O_5	Potash K_2O
		pH	ppm	ppm	ppm	ppm	N. ppm	ppm	ppm	ppm
Fd. 40										
Hanamaulu	Blank—No application	4.85	912	3	909	neg.	51.2	78.4	0.20	28.4
"	Soil + Fertilizer 1	4.97	1182	142	1040	4.5	78.0	115.3	2.60	62.5
"	Soil + Fertilizer 2	5.07	1202	62	1140	1.6	64.0	85.8	0.18	84.3
"	Soil + Fertilizer 3	4.84	1338	70	1268	neg.	48.0	130.4	0.09	122.4
Fd. 39										
Oahu	Blank—No application	7.15	678	46	632	19.5	16.0	53.0	0.25	30.9
"	Soil + Fertilizer 1	7.03	1058	216	832	24.1	30.0	82.2	0.13	38.1
"	Soil + Fertilizer 2	7.22	940	184	756	27.1	24.0	68.4	0.30	50.3
"	Soil + Fertilizer 3	7.07	1124	178	946	20.3	13.0	86.2	0.13	50.9

TABLE II—INTERACTION OF FERTILIZER SALTS AND SOILS

Results Expressed as Parts per Million in Solution

Soil	Treatment	Reaction of Soil and Fertilizer Mixture pH	Total Solids ppm	Volatile Solids ppm	Non-Volatile Solids ppm	Silica SiO_2 ppm	Nitrate Nitrogen N. ppm	Calcium CaO ppm	Phosphate P_2O_5 ppm	Potash K_2O ppm
		Soil Solutions Displaced 30 Days After First Application of Fertilizer								
Field 40										
Hanamaulu	Soil, Blank—No application..........	4.9	982	44	938	1.2	60	101	0.12	32
"	Soil, Blank + Nitrate Soda..........	5.0	1954	2	1952	3.0	172	124	0.41	31
"	Soil, Blank + Amm. Sulfate..........	4.9	1148	258	890	2.7	76	85	1.03	52
"	Soil + Fertilizer 1, No Nitrogen......	5.1	1248	156	1092	1.4	96	123	0.15	60
"	Soil + Fertilizer 2, No Nitrogen......	5.1	1240	144	1096	1.6	82	104	0.14	72
"	Soil + Fertilizer 3, No Nitrogen......	4.9	1518	60	1458	1.4	72	173	0.09	95
"	Soil + Fertilizer 1, + Nitrate Soda..	5.0	2316	70	2256	4.1	232	142	0.80	77
"	Soil + Fertilizer 2, + Nitrate Soda..	5.0	2078	111	1967	3.9	200	132	0.87	84
"	Soil + Fertilizer 3, + Nitrate Soda..	4.8	2564	120	2444	3.8	180	174	0.96	103
"	Soil + Fertilizer 1, + Amm. Sulfate..	5.0	1512	322	1190	4.5	90	122	0.68	81
"	Soil + Fertilizer 2, + Amm. Sulfate..	5.0	1352	212	1140	3.2	94	95	0.83	94
"	Soil + Fertilizer 3, + Amm. Sulfate..	4.8	1780	334	1446	3.0	80	161	0.58	118
Field 39										
Oahu Sugar	Soil, Blank—No application	7.34	1022	110	912	27.6	40	86	0.15	30
Co.	Soil, Blank + Nitrate Soda...........	7.30	3548	764	2784	23.5	332	253	0.31	75
"	Soil, Blank + Ammnoium Sulfate.....	6.66	1708	594	1114	25.0	56	159	0.14	63
"	Soil + Fertilizer 1, No Nitrogen......	7.12	1244	234	1010	17.7	42	103	0.28	41
"	Soil + Fertilizer 2, No Nitrogen......	7.49	1106	168	938	23.5	39	78	0.16	29
"	Soil + Fertilizer 3, No Nitrogen......	7.13	1166	286	880	22.3	30	98	0.17	55
"	Soil + Fertilizer 1, + Nitrate Soda..	7.07	3314	1054	2260	23.0	264	229	0.17	86
"	Soil + Fertilizer 2, + Nitrate Soda..	7.08	3488	750	2738	25.8	336	286	0.19	72
"	Soil + Fertilizer 3, + Nitrate Soda..	7.22	3996	1020	2976	30.0	324	347	0.22	84
"	Soil + Fertilizer 1, + Amm. Sulfate..	7.35	1936	694	1242	27.5	72	202	0.33	79
"	Soil + Fertilizer 2, + Amm. Sulfate..	6.81	2104	676	1428	25.8	102	211	0.17	67
"	Soil + Fertilizer 3, + Amm. Sulfate..	6.41	2178	854	1324	28.3	88	239	0.22	89

TABLE III—INTERACTION OF FERTILIZER SALTS AND SOILS

Results Expressed as Parts per Million in Solution

Soil	Treatment	Reaction of Soil and Fertilizer Mixture	Total Solids	Volatile Solids	Non-Volatile Solids	Silica SiO_2	Nitrate Nitrogen	Calcium CaO	Phosphate P_2O_5	Potash K_2O
		SOIL SOLUTIONS DISPLACED 90 DAYS AFTER FIRST APPLICATION OF FERTILIZER								
		pH	ppm	ppm	ppm	ppm	N. ppm	ppm	ppm	ppm
Field 40										
Hanamaulu	Soil, Blank—No application..........	5.02	1004	212	792	2.7	58	101.6	1.9	27.3
"	Soil, Blank + Nitrate Soda..........	4.89	2230	286	1944	1.2	244	144.5	1.5	40.6
"	Soil, Blank + Ammonium Sulfate....	4.68	1904	420	1484	6.0	176	220.1	3.3	46.8
"	Soil + Fertilizer 1, + Nitrate Soda.	4.87	2760	440	2320	2.9	212	196.5	1.7	82.3
"	Soil + Fertilizer 2, + Nitrate Soda.	5.06	2812	286	2526	1.8	204	168.0	2.9	88.7
"	Soil + Fertilizer 3, + Nitrate Soda.	4.78	2988	378	2610	2.2	196	236.0	3.5	107.0
"	Soil + Fertilizer 1, + Amm. Sulfate.	4.68	2650	542	2108	4.5	196	284.8	1.0	91.2
"	Soil + Fertilizer 2, + Amm. Sulfate.	4.63	2600	508	2092	5.5	184	266.3	1.3	105.1
"	Soil + Fertilizer 3, + Amm. Sulfate.	4.82	2832	820	2012	1.6	152	339.3	5.6	127.5
Field 39, Oahu										
Sugar Co.	Soil, Blank—No application	7.17	1462	608	854	29.1	96	105.8	1.6	36.7
"	Soil, Blank, + Nitrate Soda..........	7.10	4008	1124	2874	32.2	348	262.9	2.7	74.1
"	Soil, Blank, + Ammonium Sulfate....	6.76	4334	1442	2892	40.0	328	516.6	1.6	70.7
"	Soil + Fertilizer 1, + Nitrate Soda.	7.17	3884	768	3116	23.4	352	421.7	5.4	73.0
"	Soil + Fertilizer 2, + Nitrate Soda.	7.15	3592	574	3018	23.5	342	512.4	1.5	59.6
"	Soil + Fertilizer 3, + Nitrate Soda.	7.19	4732	718	4014	21.6	392	609.8	3.6	107.4
"	Soil + Fertilizer 1, + Amm. Sulfate.	7.17	4348	1432	2916	45.1	392	611.6	1.5	56.9
"	Soil + Fertilizer 2, + Amm. Sulfate.	6.56	4552	1200	3352	41.4	464	715.7	1.7	76.8
"	Soil + Fertilizer 3, + Amm. Sulfate.	6.58	4302	616	3686	39.9	344	835.0	2.2	91.6

TABLE IV—INTERACTION OF FERTILIZER SALTS AND SOILS

Results Expressed as Parts per Million in Solution

Soil	Treatment	Soil Solutions Displaced 90 Days After First Application of Fertilizer								
		Reaction of Soil and Fertilizer Mixture	Total Solids	Volatile Solids	Non-Volatile Solids	Silica SiO_2	Nitrate Nitrogen	Calcium CaO	Phosphate P_2O_5	Potash K_2O
		pH	ppm	ppm	ppm	ppm	N. ppm	ppm	ppm	ppm
Field 40										
Hanamaulu	Soil, Blank—No application..........	4.85	1158	144	1014	1.9	84	123	4.7	34
"	Soil, Blank, + Nitrate Soda..........	4.72	2444	520	1924	3.4	208	161	1.9	36
"	Soil, Blank, + Ammonium Sulfate....	4.63	2204	598	1606	2.8	164	208	2.9	63
"	Soil + Fertilizer 1, + Nitrate Soda..	4.84	2840	590	2250	3.8	268	227	2.1	83
"	Soil + Fertilizer 2, + Nitrate Soda..	4.82	2696	416	2280	3.1	260	183	3.4	100
"	Soil + Fertilizer 3, + Nitrate Soda..	4.84	3150	754	2396	3.4	248	273	2.5	118
"	Soil + Fertilizer 1, + Amm. Sulfate.	4.51	2748	722	2026	2.1	204	290	3.3	105
"	Soil + Fertilizer 2, + Amm. Sulfate.	4.51	2508	566	1942	2.4	228	285	3.2	107
"	Soil + Fertilizer 3, + Amm. Sulfate.	4.49	3030	1026	2004	2.9	192	354	3.9	133
Field 39, Oahu										
Sugar Co.	Soil, Blank—No application	6.75	1712	536	1176	33.1	108	133	0.8	53
"	Soil, Blank, + Nitrate Soda..........	7.02	4426	1014	3412	25.9	400	303	0.9	82
"	Soil, Blank, + Ammonium Sulfate....	6.59	4468	656	3812	39.0	328	388	1.0	146
"	Soil + Fertilizer 1, + Nitrate Soda..	7.07	5596	954	4642	35.3	400	409	1.4	94
"	Soil + Fertilizer 2, + Nitrate Soda..	7.07	4326	1294	3032	23.6	352	332	1.5	77
"	Soil + Fertilizer 3, + Nitrate Soda..	7.08	5416	1322	4094	34.7	368	397	1.3	109
"	Soil + Fertilizer 1, + Amm. Sulfate.	6.05	4610	1028	3582	33.8	315	541	0.9	68
"	Soil + Fertilizer 2, + Amm. Sulfate.	6.26	5172	932	4240	36.6	348	473	1.0	112
"	Soil + Fertilizer 3, + Amm. Sulfate.	6.44	5492	882	4610	45.7	354	517	1.3	110

Sulphur As a Fertilizer and the Sulphofying Power of Hawaiian Soils

By W. T. McGeorge

There is presented in this article a discussion of the properties of sulphur as a fertilizer and information on the sulphofying power of some Hawaiian soils. We have had no evidence, as yet, of a sulphur deficiency, as plant food, in island soils. In only one district, the Kau district of Hawaii, has response been obtained and the evidence there points toward an indirect effect, namely on the assimilation and functioning of iron or manganese or both. The data presented in this paper indicate that lack of response in some other districts is not due to an inability of the soil to oxidize or sulphofy sulphur, but that oxidation will be less active if the sulphur is applied as a surface dressing.

In the study of chlorosis—so-called Pahala blight—at Hawaiian Agricultural Company in the Kau district of Hawaii, it was found that the application of finely ground sulphur to the soil completely eliminated the chlorosis and restored the cane to normal color and development. In addition to the recovery from chlorosis, there was also a remarkable stimulation in growth following sulphur fertilization. This was shown in a greater volume of stalks, greater length of internodal joints, and notably larger leaves. The enhanced growth was further evidenced in the effect of sulphur on the D 1135 variety. This variety had been observed to be the most resistant to the type of chlorosis existant at Hawaiian Agricultural Company and, for this reason, had largely replaced Yellow Caledonia on the 2000 or more acres of chlorotic fields. Yet, on fertilizing D 1135 with sulphur, in spite of the fact that most of the plants were entirely free of chlorosis, there was a notable stimulation in growth. On the other hand, a number of fertilizer experiments with sulphur conducted on other plantations have not shown any response. Since Kilauea Sugar Plantation Company is included among the latter, we were prompted in the course of our soil studies there to examine the sulphofying power of the soils. A yellow chlorotic striping of the cane leaves, similar to that at Pahala, has been observed in several Kilauea fields.

General

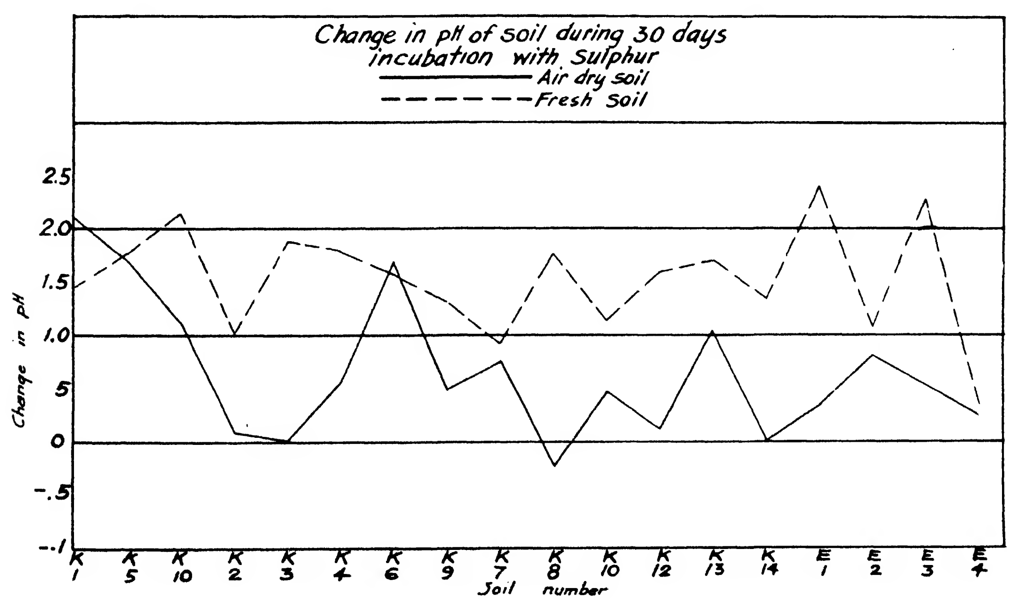
Sulphur, of itself, as a fertilizer, is more or less an inert material. Its properties may be likened to those of blood as a source of nitrogen. The nitrogen in blood is non-available to plants until it has been converted by soil bacteria into nitrate nitrogen or ammonia. So with the sulphur, which must be changed into sulphates before it is available for assimilation by the plant. The process which the nitrogen of blood undergoes in changing to nitrate is known as nitrification, while that which sulphur undergoes is known as sulphofication. Both changes are brought about by soil bacteria, namely, nitrifying bacteria and sulphofying bacteria.

Sulphofying bacteria have been isolated from soils. The sulphur is converted by the bacteria into sulphuric acid which immediately reacts with the soil bases, notably lime, and is neutralized. In the absence of an ample supply of lime or other soil bases, the application of sulphur will lead to the formation of acid soils, which are sometimes undesirable for healthy plant growth. It is essential, therefore, that one should have a knowledge of the soil types if an intelligent use of sulphur is to be made.

The Value of Sulphur

The value of sulphur in agricultural economy is attributed to several more or less variable properties, some of which follow: It has some value as a plant food; in changing from sulphur to sulphate, other forms of plant food, notably phosphorus and potassium, are made more available; the general physical condition of the soil is improved, thus enhancing aeration and movement of water; some root diseases are controlled by sulphur fertilization; and it is the most efficacious material available for the reclamation of alkali lands. In addition to the above, it has some value as a disinfectant and partial sterilizer of the soil and, where response has been obtained, there has followed a great stimulation of root development. Its effect upon the bacterial flora of the soil is of interest and usually of a favorable nature, increasing the numbers and their activity. Therefore, it is very evident that in any program of sulphur fertilization a large number of factors must be kept in mind, including the sulphur requirement of the plant, the sulphur content of the soil, mode and form of application, whether with or without inoculation with essential bacteria, etc.

Plant food value: All crop plants contain sulphur, both as organic and inorganic compounds, many requiring more sulphur than phosphorus. Up to a comparatively recent period little attention had been given to the possibility of a sulphur deficiency, it being an incidental constituent of many commercial fertilizers and also being present to a small extent in rain water. Superphosphate contains 8 per cent, ammoinum sulphate 24 per cent and potash 18 per cent sulphur. All artesian



waters contain appreciable amounts of sulphates, so there is little or no probability of any deficiency of sulphur as plant food on plantations irrigated with pump water. The only localities in which we might anticipate sulphur deficiencies are in our mauka lands or other areas where rainfall is high and the soils are subjected to heavy leaching. At this point it is of interest to note that at both Grove Farm and Kilauea no response to sulphur has been obtained. Sulphur as plant food has found extensive application, and excellent response is being obtained, in the northwestern states of the mainland. At a number of mainland experiment stations, where conflicting results were obtained in phosphate experiments, it has been found that in many cases response was due to the sulphate present in superphosphate and not from the phosphorus.

Biological value: Many soil workers look upon lowered productive capacity of soils as largely due to neglect of the microbiological machinery of the soil. They lay great stress upon the value of microorganisms in the elaboration of available plant food and the production of a healthy medium for root development. For this reason the effect of sulphur upon biological activities has been extensively studied. and its effect has been shown, on the whole, to be favorable to the development of bacteria. Gypsum, too, greatly stimulates nitrification in most soils, so it is evident that the inorganic products of sulphofication should also work for enhanced bacteria development.

Indirect value of sulphur: As a result of the biological activities connected with the conversion of sulphur into sulphates, several additional factors enter to add to the beneficial effects of sulphur fertilization. Due to the formation of sulphuric acid, there is a solvent action toward all other plant food elements which are present in the soil in insoluble forms. Growth stimulation will often result from sulphur fertilization on soils deficient in available phosphorus or potash.

Physical effects: On incubating a clay soil with sulphur, that is, on mixing a soil with sulphur, bringing to optimum moisture content and allowing to stand for a week or more, a flocculation of the clay particles will result, accompanied by a notable improvement in the mechanical condition of the soil. We have found that for the highly dispersed clay present in Kilauea soils this method is very effective for improving the mechanical condition. This flocculation is probably due to the formation of calcium sulphate and to the temporary presence of sulphuric acid during the sulphofying process, both of which are active flocculants for clay.

Plant diseases: The outstanding successes in the use of sulphur for the control of plant diseases are those of potato scab and sweet potato scurf. Its value here is due to a change in the reaction of the soil to a range in which the causal fungi cease to thrive. Lipman, at the New Jersey Experiment Station, found that sulphur retards the development of wireworms, white grubs and some other infecting insects. It should be mentioned at this point that James Campsie, manager of Hawaiian Agricultural Company, has noted a complete elimination of wireworm injury at Pahala since fertilizing with sulphur, but we have no evidence to show whether this is due to a destruction of the wireworm or because the rapidity of seed germination is so greatly increased that it minimizes the ravages of the worm.

Field experiments with sulphur: As already stated, the value of sulphur in the fertilizer program was for a long time regarded as unimportant. Plant analyses showed the presence of only small amounts of this element. The amount carried down by the rain, as well as that added incidentally as a constituent of commercial fertilizer, was considered adequate, in spite of the fact that a large amount of sulphate was, and is, lost annually from soils in the drainage water. The above attitude, however, largely underwent revision following the work of Hart and Peterson at the Wisconsin Experiment Station. Their investigations showed that sulphur in the plant, like nitrogen, is largely present in organic forms. So by determining the sulphur content of the plant by an analysis of the plant ash, the sulphur is largely lost in the products of combustion. They made many direct analyses of plants, that is, without ashing, and found much larger amounts of sulphur present than previous analyses had shown. Many plants showed a remarkably high sulphur content, notably cabbage and turnips, which contained two to three times as much sulphur as phosphorus.

Following the work of Hart and Peterson, extensive fertilizer experiments with sulphur were conducted. There followed the variable results, which were greatly clarified by Lipman and his co-workers in the discovery of sulphofying bacteria in soils. While the oxidation of sulphur may have been known to be associated with the activities of soil organisms, it remained for Lipman to isolate a number of these and utilize them for inoculating sulphur before applying it to soils. There is much evidence that inoculated sulphur is more effective than uninoculated sulphur, and that less is required.

Field experiments conducted on the mainland have been more or less conflicting, some recording beneficial results, some a detrimental effect, and some no response whatever. This is no doubt due to the different sulphur requirement of plants, difference in soil types, especially the initial reaction, and also the presence or absence in the soil of sulphofying bacteria. While most soils possess the property of oxidizing sulphur, additional inoculation will often stimulate oxidation. This has led to the appearance on the fertilizer market of a product (sulphur) to which has been added the sulphofying bacteria, thus assuring active sulphofication as soon as the sulphur is turned under and the moisture content of the soil is at optimum. Some have found that a reasonable amount of organic matter is essential, notably stable manure or other well-rotted forms of organic material. Also, many have enhanced the value of sulphur by mixing it with commercial fertilizer.

A great deal of experimental investigation covering many phases of sulphur fertilization, has been conducted at the New Jersey Experiment Station. The procedure which they have developed, involving the composting of soil, manure, phosphate rock and sulphur, as a means toward the farmer preparing his own superphosphate, is of interest. They have clearly demonstrated the value of sulphur in increasing the availability of phosphorus, and the further value of applying the two together. In our island soils, high in the oxides of iron and aluminum, there is some possibility that sulphur application with phosphate might retard fixation to unavailable form. In fact there has been some evidence of this at the Hawaiian Agricultural Company, where it is the practice to supplement sulphur applications with phosphate.

Experimental

At the time sulphur fertilization of Pahala soils was initiated, the oxidation of sulphur appeared to be very rapid and, for this reason, no attempt was made to compare their rate of sulphofication with other island soils or with those of the mainland of known sulphofying power. The following experiments were prompted by lack of response in some of the other island districts, notably Kilauea.

The soils selected for these experiments included 14 samples from Kilauea Plantation. 4 from Ewa Plantation, 2 from Waialua Plantation and 1 from Hawaiian Agricultural Company. The sulphofying power was determined by mixing 0.1 gram of finely ground sulphur with 100 grams of soil, adding water to bring to optimum moisture content, and incubating at room temperature, in the dark, for thirty days. Distilled water was added each week to maintain the moisture at optimum. At the end of this time the reaction of the soil and the amount of water-soluble sulphate was determined. In the Kilauea and Ewa soils the sulphofying power of the soils, both fresh from the field and after drying in the air, was determined. The data are given in the following tables. As a check upon the change in reaction, 100-gram samples of soil were also incubated without sulphur, and these results are given in column three of the tables. The difference between this reaction and that of the soil incubated with sulphur was taken as the change produced by the oxidation of the sulphur. Similarly water-soluble sulphate was determined in both sets of incubations and correction made for that present in the unsulphured soil.

TABLE I

Showing change in reaction and per cent sulphur sulphofied in fresh soils.

Soil No.	Description of Soil	pH after incubation without sulphur	pH after incubation with sulphur	Change in pH	Per cent sulphur sulphofied
	Kilauea Good Fields				
K1	Brown clay loam	6.34	4.87	1.47	32.8
K5	Red clay loam	6.83	5.07	1.76	16.5
K10	Red clay loam	7.13	4.98	2.15	36.5
	Kilauea Fair Fields				
K2	Black clay loam	7.96	6.92	1.04	47.8
K3	,, ,, ,,	7.30	5.42	1.88	29.5
K4	Yellow clay loam	7.33	5.52	1.81	45.4
K6	,, ,, ,,	6.35	4.78	1.57	25.9
K9	Brown clay loam	5.54	4.32	1.32	15.9
	Kilauea Poor Fields				
K7	Yellow clay loam	5.31	4.38	.93	12.0
K8	,, ,, ,,	7.79	6.03	1.76	40.4
K11	,, ,, ,,	7.17	6.02	1.15	41.5
K12	,, ,, ,,	7.40	5.80	1.60	37.0
K13	,, ,, ,,	7.26	5.54	1.72	30.2
K14	,, ,, ,,	7.91	6.57	1.34	39.6
	Ewa Soils				
E1	Red clay loam	7.72	5.31	2.41	73.4
E2	Black clay	8.47	7.40	1.07	59.7
E3	Red clay loam	7.54	5.27	2.27	63.4
E4	Black clay-limed	8.35	8.01	.34	41.8

TABLE II

Showing change in reaction and per cent sulphur sulphofied in air-dried soils.

Soil No.	Description of Soil	pH after incubation without sulphur	pH after incubation with sulphur	Change in pH	Per cent sulphur sulphofied
		Kilauea Good Fields			
K1	Brown clay loam	8.08	5.96	2.12	16.8
K5	Red clay loam	7.32	5.63	1.69	19.5
K10	" " "	7.91	6.81	1.10	17.6
		Kilauea Fair Fields			
K2	Black clay loam	7.93	7.84	0.09	57.2
K3	" " "	7.64	7.64	......	29.1
K4	Yellow clay loam	7.82	7.28	0.54	40.9
K6	" " "	6.56	4.90	1.66	21.4
K9	Brown clay loam	5.02	4.53	0.49	13.7
		Kilauea Poor Fields			
K7	Yellow clay loam	5.37	4.64	0.73	11.8
K8	" " "	7.89	8.13	......	42.2
K11	" " "	7.91	7.44	0.47	31.0
K12	" " "	8.05	7.93	0.12	38.7
K13	" " "	8.08	7.05	1.03	28.4
K14	" " "	8.11	8.11	......	43.2
		Ewa Soils			
E1	Red clay loam	7.62	7.28	0.34	......
E2	Black clay	8.18	7.37	0.81	62.0
E3	Red clay loam	7.35	6.83	0.52	......
E4	Black clay-limed	8.26	8.01	0.25	84.0
		Waialua Soils			
W1	Red clay loam-limed	8.47	8.06	0.41	73.2
W2	" " "	7.69	6.15	1.54	32.0
		Hawaiian Agricultural Co. Soils			
P1	Brown silt loam	7.84	5.71	2.33	62.4

Conclusion

While the above data are taken from a limited range of plantation soils, the conclusion seems warranted that our island soils probably all possess the power to oxidize sulphur quite readily. With the soils from Kilauea we have grouped the data according to a classification of the fields, but no relation between such a classification and sulphofying power is evident. On the other hand, as compared with mainland soils, the sulphofying power for a thirty-day period is rather low. This also is true when comparing Kilauea soils with the other soils given in the tables.

In our biological studies on Kilauea soils, we have made it a point to make our observations upon the soil samples fresh from the field before they have been allowed to dry and, where possible, repeated our studies upon the air-dry soil, as well. This procedure was adopted because of the known property of Hawaiian soils to be materially changed in chemical, biological and physical properties by air

drying and, for this reason, air-dry soils are apt to give misleading results. That this holds true, for the sulphofying power, may be readily observed by an examination of the data given in Tables I and II. Drying the soils in the air has greatly increased the buffering property, in other words, the ability of the soil to resist change in reaction. While the soluble sulphate shows that on the whole there was just as much sulphur sulphofied in the soils after they had been dried, the acidity formed, as measured by the hydrogen electrode, is less. In some cases, in spite of considerable sulphofication, there was no change whatever in the reaction.

There is some evidence that the highly dispersed clay which is present in Kilauea soils, imparts greater buffering properties to the soil from poor fields than it does to the soil from good fields. A comparison of samples K2 and K3 is also of interest. They are from adjacent areas in the same field and are similar, except that K2 had received a heavy mud press application which greatly increased the sulphofying power of the soil. It is also significant that the change in reaction of the Pahala soil, which is taken from a field that responds to sulphur, is greater than any other of the soils examined, which would indicate, too, that the soil is less strongly buffered. The amount of sulphur sulphofied is also very high.

The results indicate that one should not use soils which have been dried in the air if one wishes to study the sulphofying power of the soil. While the amount of sulphur sulphofied is not greatly different, there is a wide divergence in the change in reaction, a knowledge of which is essential in interpreting the effects of sulphur fertilization.

There is much, too, of practical significance in this observation which suggests that if one is adding sulphur to correct chlorosis or to produce an increase in the acidity of the soil, a surface application should be avoided where possible. The surface layer of soil will be more strongly buffered, thus offering greater resistance to change in reaction, because it has been subject to the periodical dry periods and exposed to air. Then, too, for active sulphofication the presence of moisture to approximately optimum moisture content of the soil is highly essential, sulphofication decreasing with both decrease or increase in soil moisture away from optimum, and more uniform moisture content is to be found in the below-surface soil.

References to literature have been purposely omitted on account of the large number to be found. However, a thorough discussion of the problem of sulphur fertilization may be found in either of the two following bulletins:

1. **An Investigation of Sulfur as a Plant Food, by G. A. Olson and J. L. St. John, Washington Experiment Station, Bulletin 165, 1921.**
2. **Biochemical Oxidation of Sulfur and Its Significance to Agriculture, by J. S. Joffe, New Jersey Experiment Station, Bulletin 374, 1922.**

The Nitrifying Power of Kilauea Plantation Soils and the Influence of Temperature and Physical Condition on Nitrification

By W. T. McGeorge

For some time past we have been conducting a rather intensive search for the factors associated with the low fertility of the soils of Kilauea Sugar Plantation Company. As one phase of this investigation, the availability of nitrogen has been studied.

It is the practice on this plantation to fallow cane land between plantings, either by allowing cattle to run the land or by leasing it to pineapple planters for a period of four years. Following this period of fallow, the cane gives little or no response to nitrogen in the plant crop. Also, it is a significant feature of this program that, in general, plant cane on the poor fields is usually superior in growth as compared to the ratoons which follow. This better yield, too, is often accompanied by a better quality of juice. As an example, it may be of interest to cite a field of Uba cane which produced 3.5 tons of sugar per acre on the plant crop and in the first ratoon only 1.5 tons of sugar per acre, accompanied by a quality ratio of 20 to 30 in the juice.

The response to, and value of, the fallow is therefore an outstanding feature of the soil fertility problem at Kilauea. It is well known and widely recognized that the principal effect of a fallow is to stimulate the microbiological machinery of the soil. The absence of any significant response to nitrogen, following the fallow, suggests that the activities of the bacteria, the functions of which are to supply nitrate to the plant, are greatly enhanced. Naturally, the question arises, is this stimulation of bacterial activity again reduced by the time the crop reaches the ratoon period and, if so, to what extent, if any, does this influence the yield of ratoon cane and the purity of the ratoon juice?

We know from previous investigation on Hawaiian soils that nitrification in virgin soils is very low, and that on plowing these soils, thus aerating and exposing them to the sunlight, a notable stimulation in nitrification results. It has been further demonstrated that after the plowed soil has been allowed to settle, and become rematted, nitrification decreases. This property is especially true of heavy clay soils. The soils which characterize the poorer fields at Kilauea are yellow clay types, the clay displaying extremely colloidal properties, and they are usually in a highly dispersed state. Such soil, we anticipate, should show wide ranges in degree of nitrification according to their physical state, because in such a bacterial phenomenon it is necessary to differentiate between the nitrifying power of the soil and the influence of chemical or physical conditions upon the environment in the field.

Experimental

The first part of this work involved the selection of a number of fields which if classified as to cane yields, may be regarded as poor, fair or good. Soil samples representing the first foot of soil were taken from these selected fields, and on the following day the nitrate content was determined and nitrification tests were also started. The soils were then dried in the air and another set of nitrification tests started. The nitrifying power of the soil is determined by placing 100 grams of soil in a glass tumbler, adding enough water to bring the soil moisture to optimum, covering the tumbler with a glass cover, and allowing the whole to stand for a period of twenty-eight days, adding water from time to time to maintain the moisture content at optimum. If it is desired to determine the nitrifying power for ammonium sulphate or blood, known amounts of these materials are added. The incubation of the soil, without added nitrogen will give the nitrifying power of the soil for its own nitrogen. The latter is the most important because it serves, in a manner, as an indication of the availability of the soil nitrogen and is a test of the nitrogen supply upon which the cane must draw between fertilizer applications. A short description of the soil and age of cane at time of sampling is given as follows:

Field 1—a good field. Ratoon crop was just starting and soil still exposed to the sun.
Field 7—a good field. Small Uba, just covering in.
Field 21—a good field. Large Badila cane already covered in and the soil shaded.
Field 2—a fair field, heavy clay soil. Large Badila cane. Two samples were taken in this field, one in the spot where mud press had been dumped, and the other taken to represent the rest of the field. The cane was almost twice as big in the former as in the latter.
Field 5—a fair field. Small Uba cane, soil not yet shaded.
Field 16—a fair field, large cane, Yellow Tip.
Field 12½—a poor field, ratoons just starting and field had just been fertilized.
Field 14—a poor field, large Badila cane.
Field 24—a poor field. Two samples were taken from this field. One from a section which had just been plowed, and the other from a section where Yellow Tip ratoons had just covered in.
Field 28—a poor field, large D 1135 cane.
Field 37—a poor field, sample taken in Yellow Tip cane about three feet high.

The nitrate content of the above soil samples is given in the following table:

TABLE I

Showing nitrogen present as nitrate and nitrite in the soils fresh from the field, expressed as parts per million nitrogen in dry soils.

Field No.	Classification	p.p.m. nitrogen as nitrate	p.p.m. nitrogen as nitrite	pH
1	good	11.4	none	8.08
7	”	4.4	”	7.32
21	”	10.1	.02	7.91
2 mud press	fair	3.1	trace	7.93
2	”	1.4	.31	7.64
5	”	4.8	.06	7.82
11	”	5.8	.08	6.56
16	”	8.4	.04	5.02
12½	poor	29.1	none	5.37
14	”	2.1	.10	7.80
24 plowed	”	22.1	.31	7.91
24 ratoon	”	3.1	none	8.05
28	”	2.4	.82	8.08
37	”	3.0	.08	8.11

In the nitrification of organic nitrogen, it is changed first by the bacteria into ammonia, then nitrite, and finally nitrate. The nitrite content of the soils was, therefore, included in the above table on the basis that this might be of some value in estimating the rate of nitrification in the field. A high nitrite content would indicate sluggish nitrification. It will be noted that there is a tendency toward no nitrites in the fields under fallow or exposed to the sun, with a further tendency toward increase in nitrites as the cane covers in, shuts off the sun, and cools the soil. The highest nitrite content is shown by the soil from Field 28, and the sample was taken in big cane where the soil was wet and cold. A comparison of the samples from Fields 2 and 24 is of interest. In the former, the mud press has apparently greatly increased nitrification as shown by the higher nitrate content and the absence of nitrite in this area. The samples from Field 24 show the effect of plowing upon the availability of nitrogen, 22.1 parts per million nitrate nitrogen being present in the plowed section of the field as compared with 2.1 parts per million in the soil under crop. This is indicative of the active nitrification which will follow cultivation, and evidence of the higher availability of nitrogen for the plant crop as compared with the ratoon crops.

The nitrifying power of the soil for its own nitrogen, that is, the availability of the soil nitrogen, was determined by keeping the soils at optimum moisture for twenty-eight days in the laboratory and the amount of nitrate formed over this period was determined. The results are given in the following table:

TABLE II

Table showing nitrogen present nitrified by incubating the fresh soil for twenty-eight days at optimum moisture content and room temperature. Results are given in parts per million nitrogen in dry soil.

Field No.	Nitrogen as nitrate after incubation	Nitrogen present in soil before incubation	Nitrogen nitrified by difference	Total nitrogen in soil	Per cent soil nitrogen nitrified
1	24.0	11.4	12.6	3700	.34
7	14.0	4.4	9.6	3200	.30
21	18.0	10.1	7.9	3700	.21
2	14.0	3.1	10.9	3900	.28
2	12.0	1.4	10.6	2600	.41
5	14.0	4.8	9.2	3700	.25
11	12.0	5.8	6.2	3400	.18
16	14.0	8.4	5.6	3800	.15
12½	38.0	29.1	8.9	3200	.28
14	16.0	2.1	13.9	3500	.40
24	32.0	22.1	9.9	3200	.31
24	17.0	3.1	13.9	3500	.40
28	15.0	2.4	12.6	3900	.32
37	23.0	3.0	20.0	3200	.63

The availability of nitrogen in Kilauea soils, as measured by the above, indicates that nitrification is on a par with other island soils but much less than that of mainland soils. Having recently completed a study of nitrification in Ewa soils, it is of interest to compare the data from the two plantations of such widely different fertility. The fourteen samples of Kilauea soils showed under field

conditions an average of 7.9 parts per million nitrogen with a minimum of 1.4 and a maximum of 29.1, while in twenty-eight samples of Ewa soils the average was 5.7 with a minimum of 2.0 and a maximum of 22.4. On the other hand, the rate of nitrification of the soil nitrogen, as measured by laboratory methods, shows more active nitrification under optimum conditions in the Kilauea soils than the Ewa soils. The average nitrate formed in the fourteen Kilauea samples was 10.8 with a minimum of 5.6 and a maximum of 20.0, while in the Ewa samples the average was 6.8 with a minimum of zero and a maximum of 24.9.

The active nitrification in Kilauea soils was further evidenced by a determination of the rate of nitrification in the same fourteen soils after drying in air and then bringing back to optimum moisture and incubating for twenty-eight days. These results are given in the following table and in Fig. 1.

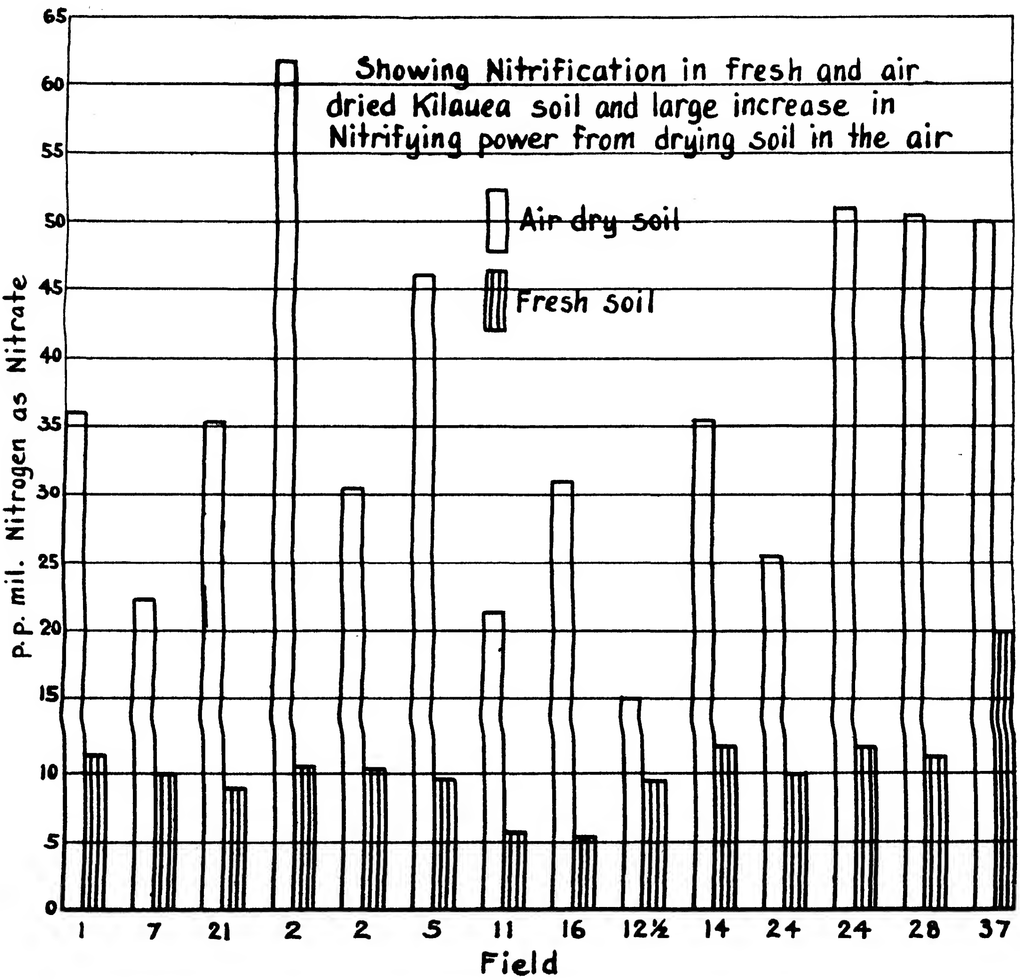


Fig. 1

TABLE III

Showing amount of soil nitrogen nitrified by incubating the air-dried soil for twenty-eight days at optimum moisture content and room temperature. Results are given in parts per million dry soil.

Soil No.	Nitrogen nitrified in air-dry soil	Per cent nitrogen nitrified	Nitrogen nitrified in fresh soil	Increase in nitrification by air drying
1	37.6	1.02	12.6	25.0
7	24.6	.77	9.6	15.0
21	35.9	.97	7.9	28.0
2	63.9	1.64	10.9	53.0
2	31.6	1.21	10.6	21.0
5	47.2	1.27	9.2	38.0
11	23.2	.68	6.2	17.0
16	32.6	.86	5.6	27.0
12½	14.9	.47	8.9	6.0
14	35.9	1.03	13.9	22.0
24	25.9	.81	9.9	16.0
24	51.9	1.48	13.9	38.0
28	50.6	1.29	12.6	38.0
37	50.0	1.57	20.0	30.0

Here again nitrification is, on the whole, more active in Kilauea soils than in Ewa soils. That is, there is a greater increase in nitrification from drying the soil in the air. It is believed that this is due to the more humid environment at Kilauea and the fact that most of the soils are, or at one time were, quite acid, while the Ewa soils are in most part neutral or slightly alkaline. The acid soil environment at Kilauea has apparently effected a greater degree of hydrolysis of the organic nitrogen compounds and thus prepared them for more active nitrification under optimum conditions, such as prevailed in the above incubations.

Judging from the data which have just been presented, nitrogen would hardly be considered as a limiting factor in the fertility of Kilauea soils. But, on carefully considering the above, we were more or less reluctant to accept these data as final. Laboratory nitrification tests are conducted at temperatures and under conditions of aeration and moisture content optimum for the nitrifying bacteria, which is far from true in the fields at Kilauea. On this basis we planned to study the question further by conducting our nitrification tests at lower temperatures and with limited aeration. Not having sufficient material left from the above set of samples, and all being dry, two composites of the air-dry soils were prepared, one from Fields 7 and 21, good fields, and the other from Fields 24, 28 and 37, poor fields. Nitrification in these was determined in the manner already described, in duplicate, one set at room temperature, 26° C. (78° F.), and the other at 20° C. (68° F.). The results are given in the following table:

TABLE IV

Showing amount of soil nitrogen nitrified by incubating the air-dried soil at optimum moisture content comparing 26° and 20° C. Results are given in parts per million dry soil.

	26°	20°
Soil 7-21	47	47
Soil 24-28-37	72	60

The results indicate a silght reduction in nitrification at the lower temperature, so an additional set of soil samples was obtained for nitrification tests on the fresh soils and, for comparison, four soils from Ewa Plantation were included. The stage of cane growth on the fields from which these samples were taken was as follows:

Field 1—ratoon cane about four feet high.
Field 7—(a) big cane, Uba, covered in.
(b) adjacent to (a) plowed and not planted.
Field 21—big cane, Badila, just ready for harvest.
Field 2—plant crop just harvested, soil bare.
Field 5—big cane, Yellow Tip.
Field 16—ratoons just starting, soil bare.
Field 12½—cane 4-5 feet high, lots of weeds.
Field 14—big Badila ready for harvest.
Field 19—ratoon cane about 4 feet high.
Field 24—(a) big cane check plots of an experiment, nitrogen only.
(b) " " nitrogen, potash, phosphate plot.
(c) " " coral sand plot.
Field 28—ratoons just harvested, soil bare.
Field 37—big Uba, ready for harvest.

The samples from Ewa Plantation were taken from Fields A, 1, C and 11. The two former are red clay soils, and the two latter are black clay soils. The nitrifying power for the soil nitrogen at 26° and 20° is given in Table V, experimental procedure being the same as already described.

The reduction in temperature of 6° C., equivalent to 10° F., has brought about a notable reduction in nitrification. Calculating this loss on a percentage basis, taking the nitrate nitrogen formed at 26° as an optimum, there is a loss shown of 15 to 100 per cent in nitrate formed from the Kilauea soils, and only 0 to 8 per cent loss in the Ewa soils.

The data in Table V were obtained under well-aerated conditions so, in order to more closely approach field conditions, an attempt was made to limit aeration. This was done by pressing the soil down tightly in glass tumblers, after water had been added, to bring the soil to optimum moisture and before the period of incubation. The nitrification under such a treatment is given in Table VI.

TABLE V

Showing the comparative nitrifying power of soils at 26° and 20° C., fresh soil at optimum content. Results given in parts per million dry soil.

Field No.	Nitrogen as nitrate in soil before incubation	Nitrogen as nitrate in soil after incubation 20°	Nitrogen as nitrate in soil after incubation 26°	Nitrogen as nitrate formed at 20°	Nitrogen as nitrate formed at 26°	Loss at 20° as compared to 26° by difference	Per cent loss at 20° as compared to 26°
KILAUEA							
1	4.8	27.5	31.5	22.7	26.7	4.0	15
7a	3.7	26.7	43.0	23.0	39.3	16.3	41
7b	14.7	31.9	57.0	17.2	42.3	25.1	59
21	4.8	29.8	41.5	25.0	36.7	11.7	32
2	18.9	43.0	59.5	24.1	40.6	16.5	41
5	7.3	25.7	60.4	18.4	53.1	34.7	65
16	9.7	31.5	45.5	21.8	35.8	14.0	39
12½	3.0	26.1	50.4	23.1	47.4	24.3	51
14	4.5	39.7	50.4	35.2	45.9	10.7	23
19	6.9	26.7	47.2	19.8	40.3	20.5	51
24a	9.0	33.0	70.8	24.0	61.8	37.8	61
24b	6.7	61.7	79.0	55.0	72.3	17.3	24
24c	6.7	41.5	66.1	34.8	59.4	24.6	41
28	7.5	29.9	51.8	22.4	44.3	21.9	49
37	3.0	29.9	41.0	26.9	38.0	11.1	29
24d	4.3	11.0	33.0	6.7	28.7	22.0	77
24e	32.0	15.0	36.0	......	4.0	4.0	100
EWA							
A	29.5	29.0	25.5	......	......	......	......
C	12.2	19.5	20.0	7.3	7.8	.5	6
1	1.5	18.0	19.5	16.5	18.0	1.5	8
11	10.8	14.0	13.0	3.2	2.2	......	......

TABLE VI

Showing the effect of limited aeration upon nitrification at 20° and 26° C. Results given in parts per million dry soil.

Field No.	Nitrogen as nitrate in soil before incubation	Nitrogen as nitrate after incubation 20°	Nitrogen as nitrate after incubation 26°	Nitrogen as nitrate formed at 20°	Nitrogen as nitrate formed at 26°	Loss at * 20° per cent of total
1	4.8	23.6	27.5	18.8	22.7	30
7a	3.7	20.0	44.7	16.3	41.0	59
7b	14.7	27.3	45.6	12.6	30.9	70
21	4.8	23.9	33.5	19.1	28.7	48
2	18.9	23.1	19.7	4.2	.8	90
5	7.3	21.2	44.0	13.9	36.7	73
16	9.7	22.1	34.6	12.4	24.9	65
12½	3.0	19.2	19.1	16.2	16.1	66
14	4.5	21.3	42.5	16.8	38.0	63
19	6.9	14.1	33.0	7.2	26.1	82
24a	9.0	20.4	29.8	11.4	20.8	81
24b	6.7	40.0	38.5	33.3	31.8	54
24c	6.7	23.1	38.5	16.4	31.8	72
28	7.5	17.2	33.0	9.7	25.5	78
37	3.0	22.0	33.8	19.0	30.8	50
A	29.5	35.0	28.2	5.5	....	....
C	12.2	13.0	18.5	.8	6.3	89
1	1.5	11.5	19.5	10.0	18.0	44
11	10.8	12.5	12.5	1.7	1.7	20

As is evident from the data given in Table VI, there is a further reduction in nitrification both at 20° and 26° under conditions of limited aeration and, since it was not possible to entirely duplicate the poorly aerated state of the worst fields at Kilauea, we might expect nitrification to be still more greatly retarded under field conditions. It is of interest to point out that temperature reduction itself had little influence on nitrification in the Ewa soils, but where temperature reduction was accompanied by reduced aeration nitrification was reduced.

Conclusion

The data which have been presented in the preceding pages offer a number of interpretations of more than passing interest and add considerable to our knowledge of mauka or humid soils, as compared to the semi-arid or irrigated soils. They indicate that the nitrogen content of the humid soils is of notably greater availability, which is not surprising when one pauses to consider the environment under which they have been formed. There has evidently been a more complete "splitting up" of the organic nitrogen compounds of plant remains within the soil confines. Excessive moisture, acid reaction and, in many cases, limited aeration of the mauka soils, have probably all been contributing factors. In the less humid environment of the makai lands, such as at Ewa, the successive steps in the decomposition of nitrogenous material, namely protein hydrolysis, ammonification,

* The data in this column were obtained by dividing the nitrate nitrogen formed at 26° in the well-aerated soil, column 6 Table V, into the loss sustained at 20° with limited aeration, the difference between column 6 Table V and column 5 Table VI.

and nitrification are continuous, due primarily to a more favorable soil reaction. Under a mauka environment, such as already described, hydrolysis would be expected to be more active with a retardation in the successive steps which follow hydrolysis. There would thus result a material accumulation of the hydrolytic products within the soil confines. In other words, organic forms of nitrogen will be of a more available nature, but environmental factors will retard bacterial activities which are essential for a further conversion into nitrate. Our soil studies tend to support this contention. The amount of nitrate which we find in Kilauea soils is consistently low and does not bear the same relation to availability as in the case of the Ewa soils, and this has led us to suspect the slow rate of nitrification in the field. When an optimum environment is supplied, nitrification becomes very active. Plowing in Field 24 increased nitrate nitrogen from 10 pounds to 66 pounds per acre foot, in Field 7 from 11 pounds to 44 pounds, while the mere exposure to the sun after harvest changed the nitrate nitrogen in Field 2 from 4 pounds to 75 pounds. The effect of air drying the soil upon nitrification, as measured by laboratory methods, is clearly shown in Fig. 1.

Only a limited interpretation of the effect of reduced temperature upon nitrification is permissible. On account of the lower availability of nitrogen in the Ewa soils there is less apparent influence, which limits the value of these data. In the Kilauea soils the decrease in nitrification is considerable, with a further decrease resulting from limited aeration. In view of this, we feel justified in stating that the standard laboratory methods fall far short of conveying to us the nitrifying power of the soil *in situ*. Such data are seriously in error unless conducted at field temperatures and under conditions of aeration approaching field conditions. We are not interested in nitrification itself as we have yet to find an Hawaiian soil in which this phenomenon is absent. What we are primarily interested in is the availability of nitrogen, or the activities of the nitrifying organisms, under field conditions. The temperature of 20° C., equivalent to 68° F., was chosen because

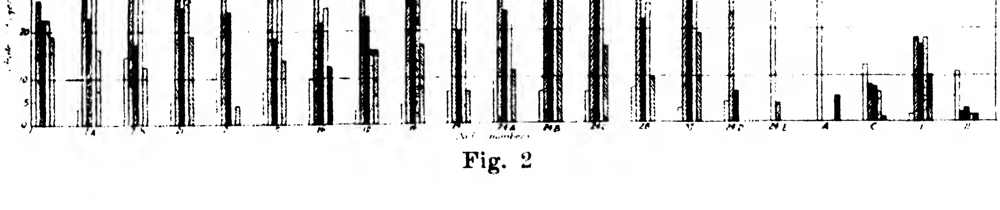


Fig. 2

the constant temperature room of the sugar technology department was available and is maintained at 20°. Weather Bureau records for Kilauea for 1928 show an air temperature variation of 60° to 82° F., with practically every week reaching a minimum of 65 or less. So it is very apparent that 20° C. falls far short of the minimum soil temperature for this plantation. It is evident, therefore, that we are not permitted to arrive at any definite conclusions from the data which we

have presented. In other words, the data presented in this paper do not tell us definitely the availability of nitrogen in Kilauea soils under Kilauea field conditions. They do, however, definitely show a very great reduction in availability at 68° F. as compared to 78° F., especially if the soil is shaded and its clay sufficiently dispersed to reduce aeration. It seems fair to assume that soil temperatures at Kilauea, at least in the mauka fields, will at times reach temperatures at 60° F., or less, and also fair to assume that nitrification will be limited to a very serious degree at such temperatures.

While the above applies specifically to Kilauea Plantation, the same would hold true for most mauka lands. The influence which this reduced nitrification has upon the fertility of mauka fields cannot be determined by laboratory methods but would have to be applied to field conditions as one phase of a field experiment. In such an experiment the changes in soil nitrogen would have to be followed through the initial period during which the soil is exposed to the sun, and the later period during which the cane shades the soil, accompanied by a determination of the assimilation of nitrogen by the cane at these successive periods.

Seedling Varieties at Ewa*

By J. L. Nicoll

For many years Ewa Plantation Company has been devoting a generous amount of area and effort to seedling propagation and selection. The work is being carried out in a systematic and thorough manner. Seedlings are planted in comparison with adjoining check plots of H 109 and yield figures are obtained on plant and ratoon crops.

Those which compare most favorably with their adjoining checks are carried to more extensive tests, while the remainder are discarded.

The following report is a summary of the performance of seedlings at Ewa that have been received from the Experiment Station and plantations. It does not include the Ewa seedlings, some of which show a great deal of promise.

(A. J. M.)

The following is a detailed report of H. S. P. A. canes as they have proven themselves at Ewa. In addition it covers more or less fully canes from other countries and local plantations as they have shown up *under Ewa conditions.* Selection to date has been based upon observation or harvest data, or more often upon combined data secured from both sources. In a report of this length it is impossible to list each individual observation or harvest of every variety. Rather

* A report by J. L. Nicoll, of Ewa Plantation Company, to W. P. Alexander, agriculturist of Ewa Plantation Company.

than run the risk of misinterpretation—inevitable if full detail of layout and environment is not also considered—this report for the most part takes the form of generalizations with indication of the applied selection and subsequent elimination.

H. S. P. A. 1911 PROPAGATION

H 425	H 427	H 431

These canes were among the earliest sent out to Ewa by the Experiment Station. They have received comparative tests with H 109 in harvest, juice data and observation. Considered both as a group and also individually they are far inferior to H 109. They have been discarded from the plantation variety areas.

H. S. P. A. 1913 PROPAGATION

H 456	H 469	H 471
H 468	H 470	H 472

Selection has been made in these varieties on the basis of both observation and also harvest of plant and ratoons. Tests were set out in Fields 13-C and 2-A. Considered as a group these canes are much inferior to H 109. Based upon our data here H 456, H 468 and H 471 are the best of the lot, or to be more accurate let us say these canes are the least inferior. Slightly below H 109 in yield as plant cane all show great loss as ratoons. Of these three H 468 has slight edge over the others. At best it cannot be considered even a possible substitute for H 109 should that variety suddenly follow in the footsteps of Lahaina.

H. S. P. A. 1914 PROPAGATION

H 467

This cane received tests similar to those received by the canes of 1913 propagation. Its yields were consistently lower than check H 109. It was recognized as not a cane for Ewa. It has been eliminated.

H. S. P. A. 1915 PROPAGATION

H 5001	H 5922	H 5946	H 5973
H 5901	H 5923	H 5949	H 5974
H 5902	H 5926	H 5953	H 5978
H 5908	H 5928	H 5962	H 5980
H 5909	H 5929	H 5964	H 5982
H 5912	H 5930	H 5965	H 5986
H 5917	H 5935	H 5971	H 5987
H 5919	H 5940	H 5972	H 5988

H 5994
H 5995
Manoa 300

Considered as a unit this group shows little promise. Although the canes here represented show wide variance in yield none approach that of H 109. Selection based upon harvest and observation has allowed few of these canes to survive. At present only the following are being retained for further trial:

H 5965	H 5986
H 5973	H 5988

Of these H 5965 and H 5973 will be plowed out after the 1929 harvest of the area to which they are planted. Indication thus points that for our conditions, of the H. S. P. A. 1915 propagated canes sent to Ewa, H 5986 and H 5988 show up best. These canes have been recently spread to larger areas in Field 19-A where more accurate harvest data may be obtained. Data to date now show that H 5988 is the better of the two as plant whereas H 5986 is the better ratooner. Although results have at times been contradictory these canes have yielded favorably when compared with H 109. They should be further tested.

Manoa 300:

This cane has shown up very poorly here. It is not a cane for Ewa. It has been discarded.

H. S. P. A. 1917 PROPAGATION

199	292	367	403	650
220	293	368	404	651
222	299	369	405	652
232	300	370	407	653
237	311	371	410	655
239	312	373	411	656
240	335	378	412	657
249	337	379	417	658
262	341	380	421	672
268	343	381	422	673
269	344	382	423	674
270	347	385	507	675
271	348	387	531	676
272	350	389	617	677
275	354	390	618	678
278	355	391	630	679
280	356	394	645	680
282	363	395	646	681
283	364	398	647	682
288	365	399	649	712

Based upon data from observation, harvest and juice analysis, these canes have gradually been eliminated from the ranks of those canes which give promise of H 109 yield. Early records point to the following as being the best of the group:

262	344	380	410	451
268	347	390	411	655
300	363	394	417	679
335	367	405	467	

Later selection again cut this list short and finally at the present time we have only the following three canes of this group on the plantation:

344	347	394

1917 O.P. 344:

We are unable to distinguish this cane from H 109. Previous records give no description of its external appearance to help identification. The Experiment

Station has no data on this point. Having examined the eye of this cane, Twigg Smith states he is unable to distinguish it from that of H 109. General indication thus shows that we have through error allowed H 109 to enter a plot of this variety and that it has since been extended under the name of the variety itself. Rather than run the risk of losing a good cane we shall continue to spread 344 as a new variety and later shall attempt to distinguish it from H 109 by a series of large area harvests.

1917 O. P. 347:

This cane started out with much promise. It received the number E 800 and was distributed outside of Ewa. Recent large area tests, however, have convinced us that it is not an H 109 competitor. One test in particular included 44 plot-to-plot comparisons. The results obtained were conclusive. Since the harvest of this test the area to which E 800 was planted has been greatly reduced.

1917 O P. 394:

This cane was once considered promising enough to be assigned the number E 801. Subsequent harvest tests have conclusively proven it to be far from H 109 in yield It now has the status of a mediocre "hanger on" and when convenient will be eradicated.

H. S. P. A. 1918 PROPAGATION

H 8136	H 8684	H 86484	H 89164
H 8139	H 86143	(H 8901 to	H 89176
H 8154	H 86441	H 89103 inc)	H 89205
H 81360	H 86465	H 89109	H 89231
H 8642	H 86472	H 89126	H 89258
	H 89282		

H 8100 Series:

These canes have had opportunity to prove their worth both as plant cane and as ratoons. Harvest data have been obtained from both. As plant cane none showed up at all well. As ratoons losses in both cane and also sugar were not as great, but even at best these canes cannot be considered in a class with H 109. At present H 81360 is the only survivor of selection. It will be eradicated following the 1929 harvest of those fields in which it is at present found.

H 8600 Series:

Not one of these canes has shown up well enough to survive selection. Of the series, H 86484 and H 86441 may be considered the best. We do not recommend them.

H 8900 Series:

Of these canes there now remain on the plantation the following:

H 8948	H 8988	H 89102	H 89258
H 8954	H 8991	H 89109	H 89282
H 8958	H 8993	H 89164	
H 8965	H 8994	H 89205	

After the next harvest of the area to which they are planted H 89164 and H 89258 will be plowed out. A classification of the canes then remaining as compared with H 109 would be as follows:

Best	Fair	Poor	No Data
H 8958	H 8994	H 8948	H 8954
H 8965	H 89102	H 8991	H 8988
H 89205		H 8993	
H 89282			

Canes H 8954 and H 8988 were brought to Ewa about a year ago on the strength of their reported yield at Waialua Agricultural Company. As yet we have no local data whatever on them. Compared with adjacent H 109 at their present age they are not striking. They will be given further tests as harvested.

Those canes above listed in the "Fair" and "Poor" classes will be given further trial, but as indications now point unless there is a marked improvement particularly in the "Poor" group they are liable to be eliminated in the next several seasons. We cannot afford to waste effort and area on mediocre canes when others with promise are awaiting trial.

The canes in the "Best" class deserve further trial. The 1929 and 1930 crops will include areas which will help to definitely establish their worth. The present status is as follows:

*H 8958:**

This cane has had a good record here at Ewa. Particularly on coral areas its yields are such that it may rightfully be placed in the class with H 109. Unfortunately our areas to date have been limited. Larger areas will be taken off in the 1929 crop and if this variety continues at the same pace it will be further extended. Ratoons hold out well. The variety has decided resistance to chlorosis. It is the best of the H 8900 Series at Ewa.

H 8965:

This cane is not outstanding at Ewa. Based on reports from other plantations it has been spread far more rapidly than it would have been strictly from its local showing. Neither on plant nor on ratoon does it come up to H 109 yield. In the 1929 crop we have a good large-area test for harvest. This with its ratoon will give us further reliable data on the variety. Until this is harvested H 8965 will not be spread and many of its small-area tests will be eliminated.

H 89205:

This cane does not fall in the H 109 class. Although by no means a poor cane it does not yield as H 109. To date it is a step better than H 8965. In both adobe and coral soil type this has held true. As a rough, general statement it may be said that this cane falls in the class "one to two tons of sugar per acre less than H 109 yield." At present we have several good tests of this variety. Yields from these will determine whether it is spread or eradicated.

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* This cane has received considerable of a boost from harvest data obtained in the 1928 crop. Its relative merits compared with those of H 8965 have been brought out clearly in these recent tests.

H 89282:

This cane has made a good record for itself both as plant and ratoon in a coral area and as plant in adobe soil. It deserves a thorough trial both as plant and ratoon on a large-scale test. Field 19-A, which is to be harvested in the coming 1929 crop will give us further data as plant cane. Comparison with the rest of the H 8900 series places this cane in much the same relative position as that occupied by H 8958. It also seems to have much the same resistance against chlorosis.

As a general summary of the H. S. P. A. 1918 propagated canes as they have proven under local conditions H 8958 and H 89282 hold most promise as understudies for H 109. More conclusive data must yet be obtained.

H. S. P. A. 1919 PROPAGATION

H 9801	H 9805	H 9809	H 9813
H 9802	H 9806	H 9810	H 9909
H 9803	H 9807	H 9811	H 9920
H 9804	H 9808	H 9812	H 9923

H 9800 Series:

Badila seedlings have never done well at Ewa. As a group this H 9800 series is exceptionally poor. At harvest each was much inferior to H 109 in yield. All had typical Badila stunted appearance, in most cases exaggerated. From the whole series we have saved only one cane—H 9806. It has little merit. All others have been plowed out.

H 9900 Series:

As yet none of these canes has shown much promise. H 9923 is the best of the three and H 9909 is next. H 9920 has been plowed out and is not at present on the plantation. H 9909 is only mediocre. H 9923 has been spread to a good harvest area. It will be taken off in plant cane in 1929.

H. S. P. A. 1920 PROPAGATION

AAA	BV	EX	G 5	J 3	NL	QG	UU
AAC	BX	EY	G 6	J 4	NN	QH	UV
AAI	B 3	E 2	G 9	J 6	NO	QI	VB
AAJ	CJ	E 3	HD	J 7	N 2	QL	VG
AAK	CN	E 5	HI	KD	N 4	QM	VK
AAQ	CU	FD	HJ	KG	N 5	QT	VQ
AAV	CZ	FF	HL	KF	N 9	QW	VR
AAZ	C 7	FJ	HP	KQ	OF	QY	VX
AA 1	DB	FQ	H 4	KR	ON	Q 3	VZ
AA 2	DD	FS	H 6	K 5	OQ	Q 4	V 6
AA 3	DI	FU	H 8	LD	OU	Q 8	V 9
AA 4	DL	FX	H 9	LH	OW	RD	WG
AA 5	DP	FY	IG	LP	O 4	RH	WJ
AA 6	DR	FZ	II	LW	O 5	RJ	WM
AA 7	DV	F 3	IK	LX	PD	RK	WO
AM	DY	F 6	IO	L 3	PK	RL	WP
AP	DZ	GB	IT	MD	PS	RR	XM
AT	D 2	GK	IY	MF	PU	R 6	X 5
AY	EA	GP	I 6	MT	PV	R 8	YC
A 6	ED	GV	JB	M 7	P 7	ST	YO
A 8	EF	GW	JF	M 8	P 8	S 8	20S 7
BC	EH	GX	JG	NA	P 9	S 9	20S 16
BG	EN	G 3	JM	NC	QE	TC	Waipio 2
BP	EO	G 4	JO	NH	QF	T 7	Waipio 7
							Waipio 8

First selection of the AA series based wholly upon observation pointed to the following canes as being the best:

AAI	AAV	AA 1	AA 3
AAQ	AAZ	AA 2	AA 4
	AA5		

Combined harvest data and observation bring out

AAV	AA 1	AA 2	AA 5

as the best of these canes.

Of the four thus selected indication now points to AA 5 as the best. It will be harvested in 1930 as plant on a fairly large area. This should give relatively accurate data.

The rest of the "alphabetical canes" represent a vast amount of disappointing work at Ewa. This series as a whole has been given every chance possible to develop a superior cane. Detailed harvest and observation data have been kept since their introduction and a gradual selection and elimination of the most inferior varieties have been carried out. No cane has proven itself outstanding. The six canes listed as follows have a better record than the rest.

C J	H 4	S 8
G 5	OU	UU

These canes have been planted out on a moderately large area for harvest in Field 19-A, 1929 plant. From data obtained in this test we will be able to more definitely state how they compare with H 109. To date we do not consider any of them in the H 109 class. CJ is likely the best of the group.

20S Series:

Basing our opinion upon small-area harvest as well as observation we consider neither of these canes in H 109 class. Of the two present, indication points towards 20 S 16 as the better. Before denifite action is taken on these varieties further harvest data should be obtained.

Waipio Series:

Based upon both harvest and observation data Waipio 2 and Waipio 7 have been discarded. Waipio 8, though slightly better than the others does not show much promise. Within all probability it will not survive rigid selection. It will be watched further for more conclusive data particularly on ratoons before it is definitely discarded.

H. S. P. A. 1922 PROPAGATION

Manoa 160:

This cane is much inferior to H 109. It has been discarded as unsuited to Ewa conditions.

H. S. P. A. 1923 PROPAGATION

UD 1	UD 2	UD 4	UD 5

Based upon observation data these canes have been discarded. They are not the type for Ewa. Of the group, U. D. 1 is probably the best here.

H. S. P. A. 1924 PROPAGATION

UB 3	UD 58	UD 65	UD 101
UD 50	UD 62	UD 86	UD 110

These canes were brought to Ewa with the hope that one or more might prove adapted to certain restricted areas on the plantation where H 109 cannot be grown or grows poorly because of extreme coral condition.

Of the group U. D. 62 seems to be best suited. Although not quite as resistant as U. D. 58 and 110, because of its larger stalk it is favored. As yet we have no accurate harvest data. However, in coral it has grown moderately well where H 109 has literally died out. We are spreading U. D. 62 on this type of soil. The other canes of this series will not be spread.

In the 1929 and 1930 crops we will harvest several areas of U. D. 62. This will give us data on juice as well as tonnage.

H. S. P. A. 1925 PROPAGATION

1925 Caledonia Series 1-47 inclusive
1925 Q Series 25, 61, 224.

25C Series:

All of these varieties have been given good opportunity to show their productive ability Based upon harvest (small area) as well as observation the most inferior individuals have been discarded and only the "moderately good" to 'good" canes have been retained.

Of the original complete set we have at present the following:

25 C 1	25 C 7	25 C 12	25 C 22
25 C 4	25 C 8	25 C 16	25 C 24
25 C 6	25 C 9	25 C 19	25 C 28
	25 C 30		
	25 C 38		

Based purely upon observation and reports from elsewhere we have spread 25C 4 and 25C 19 to relatively large areas. At present these canes show up very well. One large variety test including both of these canes will be harvested in 1929. It will yield good reliable harvest data. Another will be taken off in 1930.

In a small area harvest (from which 25C 4 and 25C 19 had already been cut for seed so they do not appear) this series took the following order in cane yield:

(1)	25 C 22	(5)	25 C 28
(2)	25 C 7	(6)	25 C 16
(3)	25 C 24	(7)	25 C 12
(4)	25 C 1	(8)	25 C 38

These results cannot be considered conclusive.

25Q Series:

These canes do not seem to have much future at Ewa. 25 Q 224 has been totally discarded. 25 Q 25 and 25 Q 61 have been retained on small areas purely for observation purposes. Within all probability they will not survive the next selection.

H. S. P. A. 1926 PROPAGATION

26 C 48	26 C 113	26 C 148	26 C 216
26 C 52	26 C 116	* 26 C 149	26 C 219
26 C 53	26 C 118	26 C 157	26 C 245
26 C 54	26 C 122	26 C 161	26 C 249
26 C 58	26 C 129	26 C 163	26 C 250
26 C 71	26 C 132	26 C 169	26 C 261
26 C 80	26 C 138	26 C 171	26 C 263
26 C 88	26 C 139	26 C 176	26 C 265
26 C 89	26 C 141	26 C 182	26 C 268
26 C 99	26 C 143	26 C 189	26 C 270
26 C 110	26 C 144	26 C 211	26 C 274

One selection has been made in these varieties. The following have been extended for further trial.

26 C 48	26 C 89	26 C 163	26 C 261
26 C 52	26 C 113	26 C 169	26 C 270
26 C 58	26 C 144	26 C 182	

We have as yet no harvest data on any of these canes. They are new at Ewa.

Canes From Other Plantations

Hawaiian Sugar Company:

HS Co. 38	HS Co. 480	HS Co. 507	Maka 3	Maka 5
HS Co. 50	HS Co. 483	Maka 2	Maka 4	Maka 6

These canes have had a moderately good try-out at Ewa both as harvest and also under observation. None may be considered outstanding. We do not feel they have much chance of competing with H 109 at Ewa. Those receiving further trial are:

HS Co. 38	HS Co. 483	Maka 4	Maka 5

Kohala Sugar Company:

Kohala 4	Kohala 202

Kohala 4 was planted out in two sections of the plantation. Because of extreme susceptibility to eyespot, even in our mild eyespot condition here, Kohala 4 has been discarded on observation data only, having never reached the harvest stage.

Kohala 202 is not a cane for Ewa. In plant harvest it proved consistently lower in yield than bordering H 109. It is extremely susceptible to mosaic disease. It has been plowed out and discarded.

Maui Agricultural Company:

† Paia 3	Paia 73	Paia 163	Paia 427
Paia 20	Paia 75	Paia 173	Paia C
Paia 38	Paia 86	Paia 180	Paia D
Paia 71	Paia 150	Paia 186	Paia E
			Paia F

* 26 C 149 was a late comer to the plantation. It was not present at the time of the above recorded selection. It is being carried on with this selected group on the basis of reports from elsewhere.

† The "Paia" series is the series listed at Ewa as "MACO."

These canes are at the present in process of receiving a thorough test at Ewa. To date several have shown up well in immature harvest as well as on observation.

Paia 150 is so far the best with us. Though as yet we have no large-area harvest nor juice data, we feel this cane has much possibility and its performance to date warrants it being placed in the H 109 class. It is a remarkably good cane at Ewa. Good block tests will be harvested in 1929 and 1930. We will await results from these with great interest, particularly in the matter of juice.

Paia 180 seems to be the next best. Although not quite in a class with Paia 150 it is also a good cane.

These two canes may well be considered the best of this series to date. From the group we have already eliminated several as being unsuited to local conditions. They are as follows:

75	163	C
86	427	

Of the remaining canes, excluding 150 and 180 which we have already discussed, 71, 73, 173 and F show up best. They will receive further trial on larger areas.

McBryde Series:

McBryde 1	McBryde 7

These two canes did very poorly at Ewa. Of the two, McBryde 1 is the better but it has very little merit. We are confident these canes have no future here.

Waialua Agricultural Company:

Waialua 1	Waialua 4

These canes are newcomers at Ewa. To date they do not show up exceptionally well. They have been spread to a ten-line basis and should yield juice and harvest data in 1930. Of the two, Waialua 1 appears the better. As this is based upon observation alone on moderately young cane it cannot be considered conclusive.

Wailuku Series:

Wailuku 1	Wailuku 4	Wailuku 10	Wailuku 13
Wailuku 2	Wailuku 5	Wailuku 11	Wailuku 30

As a whole this group has been disappointing. Practically all canes included have a strikingly rapid first season growth, but fall down badly during the second season and on ratoons. We are now satisfied that none are adapted to Ewa conditions. Those which have given the best yields are Wailuku 4 and Wailuku 11. It is likely that even these will be discarded in the next selection. Wailuku 4 is very susceptible to eye spot.

Canes From Other Countries

Badila:

Badila is most decidedly unsuited to Ewa. On a fair sized harvest in Field 2-A it yielded less than half as much as H 109 both in cane and in sugar. It was promptly discarded.

White Bamboo:

This cane, harvested in Field 2-A, showed a one-third loss in cane and sugar when compared with adjacent H 109. It is unsuited to Ewa. It has been totally discarded.

BH (10) 12:

This cane is a newcomer to Ewa. We have not yet had opportunity to test it at harvest. To date, as six months old cane, it compares favorably with H 109 in appearance. It will be given a thorough trial.

Cavengerie:

This cane has had one small-area harvest. In this it yielded well up to H 109. It will be extended and more conclusive data will be obtained on both plant and ratoon.

D 74:

This cane received one block harvest in 1921. Its yield was far below H 109 standard. It was promptly discarded and replanted with H 109.

P. O. J. Series:

P.O.J. 36	P.O.J. 234	P.O.J. 2714	P.O.J. 2727
P.O.J. 213	P.O.J. 979	P.O.J. 2725	

These canes are relatively new at Ewa. In the original plantings P.O.J. 36 and P.O.J. 213 developed a leaf burn which was then feared to be an imported disease from Java. These two canes were promptly dug out.

P.O.J. 234 and P.O.J. 979 matured and were taken off as a harvest. Although not quite up to H 109 and not the type we would naturally consider as Ewa cane these have shown up rather well. They will be again harvested in present areas before being spread further.

The other three canes, P.O.J. 2714, P.O.J. 2725 and P.O.J. 2727 are newcomers. They have as yet never been harvested. To date (six months of age) they show up well with surrounding H 109. They will be extended to harvest areas promptly.

Cane Ripening Experiment

HONOLULU PLANTATION COMPANY—FIELD 23 WAIMALU

By J. A. Verret, A. J. Mangelsdorf and C. G. Lennox

What happens during the ripening-off period under irrigated conditions? In general, we can say from the results of preharvest juice samples, that when we stop irrigation, Brix increases as the cane dries out and that purity, too, usually improves up to a certain point. These preharvest juice samples give us no information, however, as to whether we are gaining or losing cane weight, nor do they tell us whether the proportion of juice to fiber is decreas-

ing as the drying out process progresses. Both of these items have a direct bearing on the yield of sugar per acre. It is conceivable that even though Brix and purity were improving, tons sugar per acre might actually be decreasing, due either to loss in weight or to a decrease in the proportion of juice to fiber as a result of drying out.

It was to obtain information on these points that this ripening experiment at Honolulu Plantation Company was undertaken.

Plan of the Experiment

The first step was to find as uniform a field as possible, and so located on a railroad line that plots could be harvested from time to time without interfering too greatly with plantation procedure. The area was then to be laid out in seven different series of ten plots each. The ten plots in every series were to be distributed uniformly over the field. The first series was to be harvested shortly after irrigation had ceased—that is, at the beginning of the ripening process, the next series three weeks later and so on. The seven series were to cover a period of four months. It was felt that in this way fair samples of the field would be obtained at the successive stages of ripening.

The splendid cooperation of the plantation enabled us to carry the experiment through as planned. An undertaking of this nature costs a great deal in both time and money and cannot be carried out except with the full help of all. Both the plantation and the chemistry and sugar technology departments of the Station gave their fullest cooperation.

We believe that the information obtained justifies these efforts and expenditures and that more experiments of this nature should be harvested. Larger losses than we realize may take place through over-ripening of the cane as a result of too long an interval between the final irrigation and harvest.

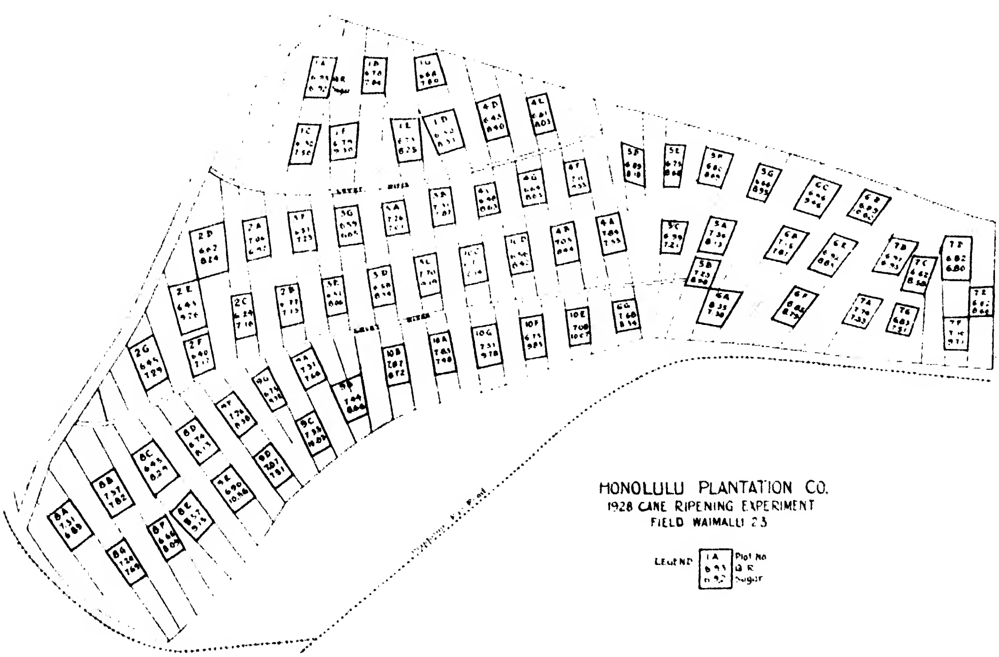


Fig. 1

General Data

The experiment was located in Field 23 Waimalu, at an elevation of about 250 feet. The soil is a red silty clay loam of fair depth.

The moisture equivalent, kindly determined by Professor H. A. Wadsworth, according to the method of Briggs and McLane, was 31.5. Using a ratio of 1.37 as determined for certain similar Hawaiian soils, gives a wilting coefficient of about 23 per cent for the soil under consideration.

The hygroscopic coefficient as determined by the chemistry department was 19.93 and the total water-holding capacity was 74.41.

The cane was H 109 plant, having been planted in October, 1926. The final irrigation in this field was completed on May 1, 1928.

A running crusher juice sample was taken separately for each of the ten plots.

The plot areas were determined by taping four sides and a diagonal. The area of the plots averaged about 0.04 acre each.

The layout of the experiment (Fig. 1) shows the distribution of the plots. It was attempted to so arrange them that each harvest would be representative of the field.

The plots in all cases were surrounded by crop cane, so there would be no outside exposure to induce faster drying than would generally take place in large fields of cane.

The soil in each plot was sampled to a depth of three feet immediately after each harvest. Percentage of moisture and nitrate nitrogen were determined on these samples by the chemistry department.

The results of these analyses are given in Tables I to VII. In Table VIII we give the rainfall and temperature during this period as furnished by Honolulu Plantation Company. In Fig. 2 we show these data graphically. The curve for the average soil moisture is shown in Fig. 3.

TABLE I

HONOLULU PLANTATION COMPANY

1928 Ripening Experiment

Series A Plots—May 25

FIRST FOOT				SECOND FOOT				THIRD FOOT			
Plot No.	Can No.	% H_2O Dry Basis	Nitrate Nitrogen P. P. M. Dry Soil	Plot No.	Can No.	% H_2O Dry Basis	Nitrate Nitrogen P. P. M. Dry Soil	Plot No.	Can No.	% H_2O Dry Basis	Nitrate Nitrogen P.P.M Dry Soil
A 1	109	24.8	15.6	A 1	110	25.6	15.2	A 1	111	25.8	13.1
A 2	25	27.1	16.4	A 2	26	26.9	15.9	A 2	27	26.7	13.2
A 3	28	28.0	16.0	A 3	29	28.4	15.0	A 3	30	26.9	14.3
A 4	24	26.3	16.8	A 4	23	26.6	20.0	A 4	22	26.1	22.1
A 5	21	27.5	23.4	A 5	20	26.4	22.4	A 5	19	26.7	19.0
A 6	34	26.3	16.3	A 6	35	26.3	15.8	A 6	36	25.5	13.6
A 7	31	26.4	15.8	A 7	32	26.6	16.4	A 7	33	25.8	16.2
A 8	118	27.5	13.3	A 8	119	27.5	10.1	A 8	120	26.7	13.2
A 9	115	27.5	19.7	A 9	116	29.0	16.7	A 9	117	27.9	14.4
A 10	112	25.3	16.2	A 10	113	26.6	14.8	A 10	114	26.1	15.8
	Average	26.67	16.95			26.99	16.23			26.42	15.49

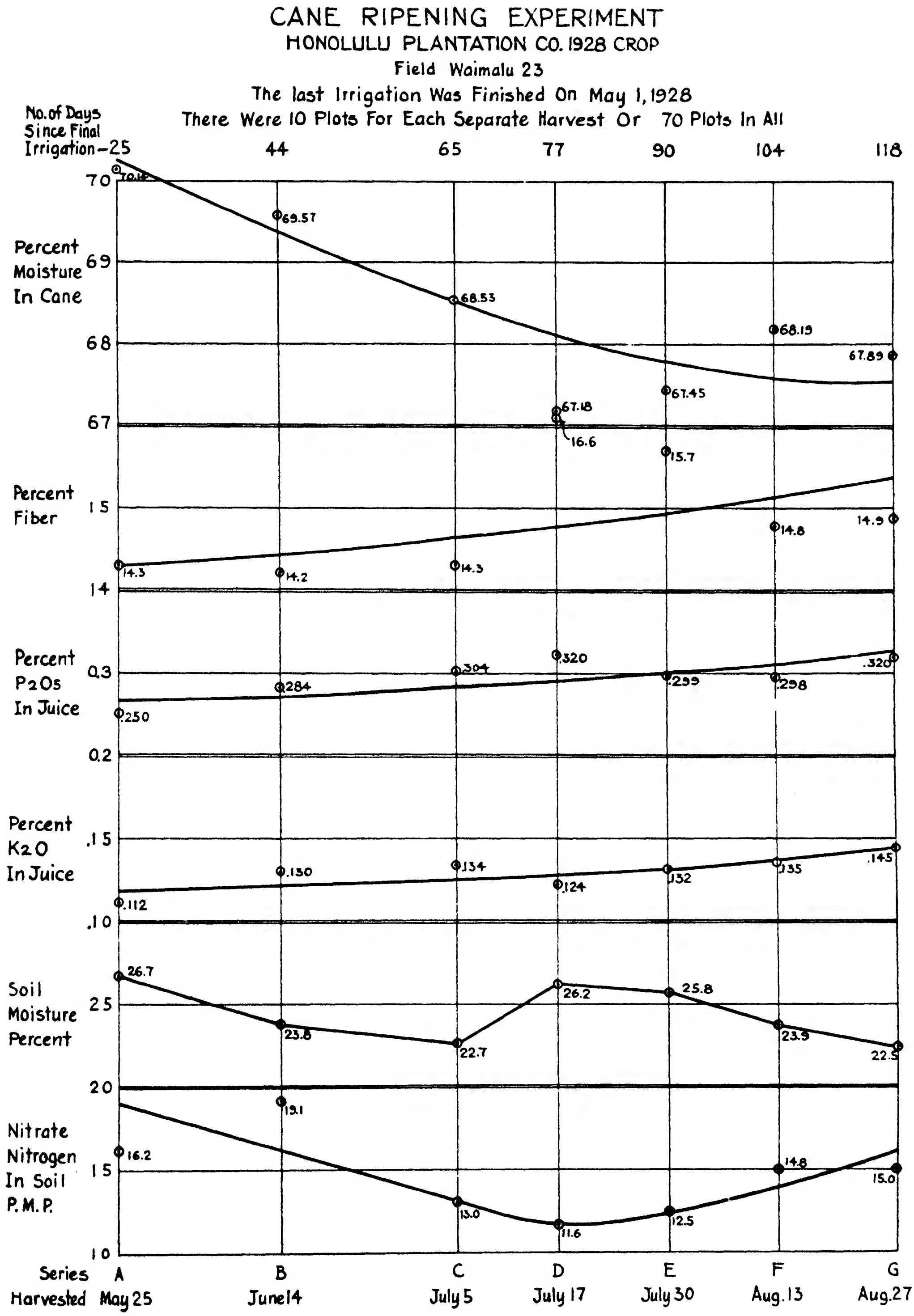

CANE RIPENING EXPERIMENT
HONOLULU PLANTATION CO. 1928 CROP
Field Waimalu 23
The last Irrigation Was Finished On May 1, 1928
There Were 10 Plots For Each Separate Harvest Or 70 Plots In All
No. of Days Since Final Irrigation–25
44
65
77
90
104
118
Percent Moisture In Cane
69.57
68.53
68.15
67.89
67.18
67.45
16.6
15.7
Percent Fiber
14.3
14.2
14.3
14.8
14.9
Percent P2O5 In Juice
.250
.284
.304
.320
.299
.298
.320
Percent K2O In Juice
.112
.130
.134
.124
.132
.135
.145
Soil Moisture Percent
26.7
23.8
22.7
26.2
25.8
23.9
22.5
Nitrate Nitrogen In Soil P.M.P.
16.2
19.1
13.0
11.6
12.5
14.8
15.0
70
69
68
67
15
14
0.3
0.2
.15
.10
25
20
15
10
Series Harvested
A May 25
B June 14
C July 5
D July 17
E July 30
F Aug. 13
G Aug. 27

Fig. 2

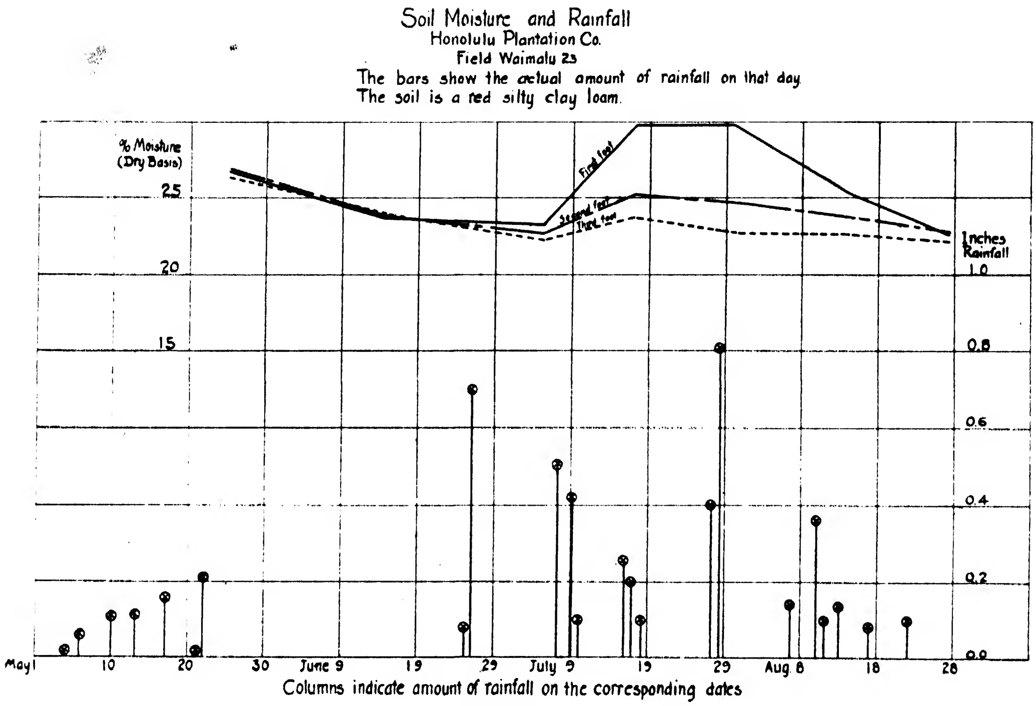


Fig. 3

TABLE II

HONOLULU PLANTATION COMPANY
Ripening Experiment—Waimalu Field 23
Series B Plots—Harvested June 14, 1928
(Soil Analysis)

FIRST FOOT			SECOND FOOT			THIRD FOOT		
Plot No.	% H_2O	Nitrate Nitrogen P. P. M. (Dry Soil)	Plot No.	% H_2O	Nitrate Nitrogen P. P. M. (Dry Soil)	Plot No.	% H_2O	Nitrate Nitrogen P. P. M. (Dry Soil)
B 1	22.5	22.9	B 1	23.2	18.4	B 1	25.0	13.3
B 2	24.1	15.5	B 2	25.2	25.8	B 2	25.3	18.8
B 3	25.3	21.1	B 3	25.2	19.5	B 3	24.1	17.0
B 4	21.5	27.9	B 4	22.3	25.1	B 4	22.5	16.1
B 5	24.8	22.6	B 5	24.4	20.2	B 5	23.8	16.2
B 6	23.6	19.2	B 6	24.1	19.3	B 6	24.4	18.6
B 7	23.8	22.4	B 7	24.1	20.9	B 7	24.8	21.8
B 8	23.2	19.9	B 8	23.0	15.3	B 8	23.2	19.2
B 9	22.9	18.4	B 9	23.9	19.3	B 9	23.3	18.4
B 10	24.4	14.7	B 10	23.3	12.3	B 10	23.5	13.1
Average	23.61	20.46		23.87	19.61		23.99	17.25

TABLE III

HONOLULU PLANTATION COMPANY

Ripening Experiment—Waimalu Field 23
Series C Plots—Harvested July 5, 1928
(Soil Analysis)

	FIRST FOOT			SECOND FOOT			THIRD FOOT	
Plot No.	Moisture in Soil (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)	Plot No.	Moisture in Soil (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)	Plot No.	Moisture in Soil (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)
C 1	21.4	14.6	C 1	21.7	12.1	C 1	22.0	12.1
C 2	23.8	17.5	C 2	22.0	15.7	C 2	22.4	12.7
C 3	23.8	13.9	C 3	23.0	11.7	C 3	22.3	11.7
C 4	24.5	15.5	C 4	23.5	13.3	C 4	22.4	12.2
C 5	24.5	12.9	C 5	22.7	11.7	C 5	23.5	11.3
C 6	23.8	18.0	C 6	23.2	12.8	C 6	23.8	13.4
C 7	22.9	9.7	C 7	23.2	13.8	C 7	22.7	12.2
C 8	23.8	12.3	C 8	23.3	12.3	C 8	22.4	9.6
C 9	20.8	14.0	C 9	21.9	12.6	C 9	21.4	12.6
C 10	22.3	13.7	C 10	21.5	12.6	C 10	21.2	12.0
Average	23.16	14.21	Average	22.60	12.86	Average	22.41	11.98

TABLE IV

HONOLULU PLANTATION COMPANY

Ripening Experiment—Waimalu Field 23
Series D Plots—Harvested July 17, 1928
(Soil Analysis)

	FIRST FOOT			SECOND FOOT			THIRD FOOT	
Plot No.	Moisture in Soil (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)	Plot No.	Moisture in Soil (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)	Plot No.	Moisture in Soil (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)
D 1	30.9	17.00	D 1	25.5	15.14	D 1	23.0	10.72
D 2	29.5	14.10	D 2	23.9	7.21	D 2	24.1	9.79
D 3	31.2	10.45	D 3	27.6	9.05	D 3	24.1	7.22
D 4	33.0	20.65	D 4	25.5	17.23	D 4	23.5	17.43
D 5	28.0	14.97	D 5	25.3	11.47	D 5	23.0	9.19
D 6	30.4	13.10	D 6	26.7	10.57	D 6	24.4	10.86
D 7	30.0	12.52	D 7	25.9	11.54	D 7	26.6	10.55
D 8	30.0	14.15	D 8	23.9	7.72	D 8	23.6	9.75
D 9	28.5	13.42	D 9	24.7	10.37	D 9	22.9	8.67
D 10	26.4	7.37	D 10	22.9	6.63	D 10	22.0	8.59
Average	29.79	13.77	Average	25.19	10.69	Average	23.72	10.28

TABLE V

HONOLULU PLANTATION COMPANY
Ripening Experiment—Waimalu Field 23
Series E Plots—Harvested July 30, 1928
(Soil Analysis)

FIRST FOOT			SECOND FOOT			THIRD FOOT		
Plot No.	Moisture in Soil (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)	Plot No.	Moisture in Soil (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)	Plot No.	Moisture in Soil (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)
E 1	32.1	12.8	E 1	26.6	15.3	E 1	22.9	12.2
E 2	30.4	14.7	E 2	24.8	11.9	E 2	23.8	10.8
E 3	31.1	15.9	E 3	25.0	13.5	E 3	22.3	11.1
E 4	26.9	12.2	E 4	23.6	12.3	E 4	22.5	8.6
E 5	29.7	10.8	E 5	23.3	10.2	E 5	22.3	11.7
E 6	30.2	13.1	E 6	25.6	11.0	E 6	22.9	10.7
E 7	27.1	13.8	E 7	23.5	14.3	E 7	23.3	9.7
E 8	29.4	16.8	E 8	25.5	12.0	E 8	23.3	9.2
E 9	30.7	13.7	E 9	24.4	11.4	E 9	22.5	17.3
E 10	30.4	14.7	E 10	25.0	13.5	E 10	22.3	10.6
Average	29.8	13.9	Average	24.7	12.5	Average	22.8	11.2

TABLE VI

HONOLULU PLANTATION COMPANY
Ripening Experiment—Waimalu Field 23
Series F Plots—Harvested August 14, 1928
(Soil Moisture)

	FIRST FOOT		SECOND FOOT		THIRD FOOT	
Plot No.	% Moisture (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)	% Moisture (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)	% Moisture (Dry Basis)	Nitrate Nitrogen P. P. M. (Dry Basis)
F 1	25.9	19.93	23.9	13.90	22.9	13.25
2	27.1	21.19	23.9	14.41	22.7	13.23
3	25.9	18.35	23.6	20.02	22.3	14.19
4	26.4	16.86	23.6	12.83	22.4	13.70
5	25.6	15.69	24.1	12.89	22.7	11.70
6	23.0	17.10	23.9	13.90	21.9	11.60
7	24.4	12.92	24.1	14.43	23.6	11.83
8	23.8	21.53	23.3	18.61	22.7	12.32
9	24.5	15.53	23.2	14.31	22.1	12.14
10	26.1	13.36	24.4	10.24	23.6	11.20
Average	25.3	17.25	23.8	14.55	22.7	12.52

TABLE VII
HONOLULU PLANTATION COMPANY
Ripening Experiment—Waimalu Field 23
Series G Plots—Harvested August 27, 1928

Sample No.	FIRST FOOT % Moisture (Dry Basis)	FIRST FOOT Nitrate Nitrogen (Dry Basis)	SECOND FOOT % Moisture (Dry Basis)	SECOND FOOT Nitrate Nitrogen (Dry Basis)	THIRD FOOT % Moisture (Dry Basis)	THIRD FOOT Nitrate Nitrogen (Dry Basis)
G 1	22.1	15.69	21.9	15.14	22.7	13.23
2	23.3	15.36	22.4	13.70	20.6	12.97
3	23.3	14.84	23.3	12.80	22.7	11.20
4	22.7	16.29	22.9	13.76	21.7	13.10
5	24.1	17.53	23.0	14.32	22.5	17.28
6	21.9	15.14	22.7	15.27	21.9	16.65
7	22.3	17.23	22.7	17.30	22.4	17.76
8	20.8	16.99	22.7	16.80	22.0	14.65
9	22.4	14.72	22.9	15.29	22.9	13.12
10	23.0	14.80	22.3	14.19	21.2	13.55
Average	22.6	15.86	22.7	14.86	22.1	14.35

TABLE VIII
RAINFALL AND TEMPERATURE
Waimalu 25 (adjacent to Field 23)
(Data supplied by Honolulu Plantation Company)

May, 1928

RAINFALL			TEMPERATURE
May 3	.02	inches	Average maximum .....80.2° F.
5	.06	"	Average minimum .....67.2° F.
10	.12	"	Average daily range....18.5° F.
13	.13	"	
17	.17	"	
21	.02	"	
22	.23	"	
Total for May	.75	"	

June, 1928

June 25	.08	inches	Average maximum .....88.2° F.
26	.69	"	Average minimum .....68.4° F.
			Average daily range....19.7° F.
Total for June	.77	"	

July, 1928

July 7	.52	inches	Average maximum .....87.6° F.
9	.44	"	Average minimum .....71.6° F.
10	.10	"	Average daily range....16.0° F.
16	.25	"	
17	.19	"	
18	.12	"	
27	.42	"	
28	.82	"	
31	.01	"	
Total for July	2.87	"	

August, 1928

August 7	.14	inches	Average maximum ....90.3° F.
10	.36	"	Average minimum .....71.0° F.
11	.12	"	Average daily range....19.2° F.
13	.14	"	
17	.08	"	
22	.10	"	

CANE RIPENING EXPERIMENT
HONOLULU PLANTATION CO. 1928 CROP
FIELD WAIMALU 23
The Last Irrigation Was Finished On May 1, 1928
There Were 10 Plots For Each Separate Harvest Or 70 Plots In All

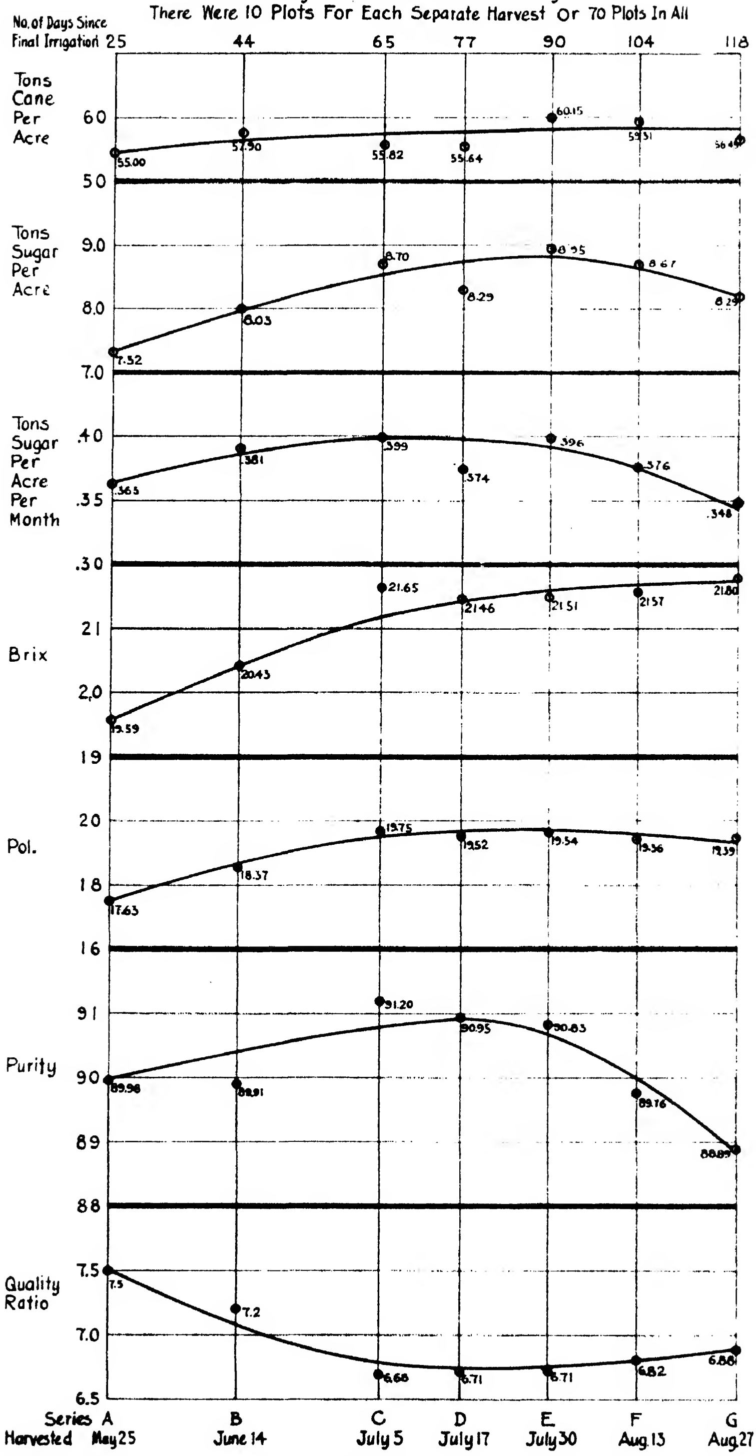


Fig. 4

Yield Data

In Tables IX to XV we give the detailed yield, by plot; and in Table XVII the results are summarized. In Fig. 4 we show these data by means of curves.

Although we chose what seemed to be a very uniform area, in fact, the most uniform area we could find, the yields from plot to plot show wide variation, the spread extending from a low yield of 43.8 tons of cane per acre to a high yield of 73.5. It is fortunate that we had ten replications of each treatment. The averages smoothed out these variations fairly well, except for the "D" series of plots, the cane yields of which are unaccountably low. The juices are more consistent. A study of the results indicates that the cane in this field was at its best from about 40 to 90 days after the last irrigation. After this period there is a rapid loss in production per acre, caused by a slight decline in cane tonnage and a rather marked decline in juice quality. This loss in actual sugar in the field is greatly increased when one adds to it the loss in growing time on the new crop. In other words, two losses are going on, first of actual deterioration in the old crop and second, loss of growing time for the next crop. One can readily see that in aggravated cases this might easily amount to a ton or more of sugar per acre.

The juices were at their best 70 days after the last irrigation. Beyond this period the purity declines at first rather slowly and then more rapidly. A loss in purity means a loss in sugar in spite of the fact that the quality ratio may remain the same or even show improvement, the improvement in the quality ratio being due to concentration of juice by evaporation, while the decrease in purity is caused by the inversion of sucrose.

We feel that more sugar may be lost than we realize when we allow some of our fields to dry out too much before harvest. This also has a bad effect on the ratoons as many stools die out and the field as a whole is slower to start out than if it had not dried out quite so much.

We are not advocating the regular irrigation of the older cane in times of acute water shortage. A given amount of water is, of course, more efficient on younger cane. Every effort should be made, however, to supply water frequently enough to prevent drying of the cane or to harvest it before the drying out has proceeded to this point.

TABLE IX

HONOLULU PLANTATION COMPANY
1928 Ripening Experiment—Field 23, Waimalu
Series A Plots—Harvested May 25, 1928
Age of Cane 20.16 Months
Twenty-five days since last irrigation

Plot No.	Area	T.C.P.A.	Brix	Pol.	Purity	App. Q.R.	T.S.P.A.	T.S.P.A. P.M.	Glucose	% P_2O_5	% K_2O
A 1	.03682	47.93	20.65	18.84	91.24	6.93	6.916	.3431	.302	.031	0.143
A 2	.03689	48.85	20.50	18.59	90.68	7.06	6.919	.3432	.307	.030	0.112
A 3	.03291	50.86	19.90	18.05	90.70	7.26	7.006	.3475	.384	.023	0.085
A 4	.03802	59.22	18.95	16.91	89.24	7.84	7.554	.3747	.501	.024	0.104
A 5	.03369	59.81	19.65	17.82	90.69	7.36	8.126	.4031	.421	.024	0.099
A 6	.04616	61.58	18.06	15.98	88.48	8.35	7.375	.3658	.637	.020	0.108
A 7	.03162	56.70	19.01	17.06	89.74	7.74	7.326	.3633	.503	.028	0.105
A 8	.03870	50.07	20.05	18.04	89.98	7.31	6.850	.3398	.369	.028	0.155
A 9	.02780	56.00	20.10	18.05	89.80	7.31	7.661	.3800	.520	.021	0.105
A 10	.03532	58.57	19.00	16.95	89.21	7.83	7.480	.3710	.582	.020	0.103
Avge.	.03579	54.96	19.59	17.63	89.98	7.5	7.32	.3632	.453	.025	0.112

TABLE X

HONOLULU PLANTATION COMPANY

Ripening Experiment—Waimalu Field 23

Series B Plots—Harvested June 14, 1928—Age 21.1 Months

Forty-four days since last irrigation

Plot No.	Area	T.C.P.A.	Brix	Pol.	Purity	App. Q.R.	T.S.P.A.	T.S.P.A. P.M.	Glucose	% P_2O_5	% K_2O
B 1	.039675	53.14	21.29	19.33	90.79	6.78	7.837	.371	.384	.030	.15
B 2	.036200	48.25	21.31	19.36	90.85	6.77	7.127	.337	.359	.030	.13
B 3	.038500	57.49	20.24	18.11	89.48	7.31	7.865	.373	.542	.029	.13
B 4	.040122	59.53	20.54	18.61	90.60	7.05	8.443	.400	.444	.026	.13
B 5	.033550	64.95	20.34	18.27	89.82	7.23	8.983	.426	.559	.022	.11
B 6	.040650	56.24	20.44	18.42	90.12	7.15	7.865	.373	.545	.027	.12
B 7	.034700	48.44	20.87	18.86	90.37	6.97	6.950	.329	.441	.021	.14
B 8	.037500	57.64	20.12	17.98	89.36	7.37	7.820	.371	.522	.045	.17
B 9	.028400	64.42	19.92	17.81	89.41	7.44	8.659	.410	.632	.030	.12
B 10	.041777	68.60	19.24	16.98	88.26	7.87	8.716	.413	.747	.024	.11
Ave.	.037107	57.87	20.43	18.37	89.91	7.2	8.027	.3809	.5175	.0284	.13

TABLE XI

HONOLULU PLANTATION COMPANY

1928 Ripening Experiment—Field 23, Waimalu

Age, 21.8 Months—Series C Plots—Harvested July 5, 1928

Sixty-five days since last irrigation

Plot No.	Area	T.C.P.A.	Brix	Pol.	Purity	App. Q.R.	T.S.P.A.	T.S.P.A. P.M,	Glucose	% P_2O_5	% K_2O
C 1	.035698	47.41	22.24	20.51	92.22	6.32	7.501	.3439	.364	.034	0.125
C 2	.038877	44.66	22.42	20.73	92.46	6.24	7.156	.3281	.283	.032	0.136
C 3	.031392	70.77	21.45	19.45	90.68	7.70	9.191	.4214	.503	.027	0.126
C 4	.037441	55.95	21.89	20.10	91.82	5.93	9.435	.4326	.396	.033	0.125
C 5	.026821	50.37	20.75	18.67	89.98	6.99	7.206	.3304	.590	.029	0.132
C 6	.034224	61.14	22.09	20.20	91.44	6.46	9.464	.4339	.415	.033	0.130
C 7	.036090	56.82	21.69	19.76	91.10	6.62	8.583	.3935	.457	.030	0.129
C 8	.044800	53.46	22.07	20.20	91.53	6.45	8.289	.3801	.350	.032	0.146
C 9	.033351	73.49	20.32	18.11	89.12	7.33	10.026	.4597	.624	.027	0.170
C 10	.027851	68.12	21.54	19.73	91.60	6.72	10.137	.4648	.426	.027	0.121
Ave.	.034655	58.22	21.65	19.75	91.20	6.68	8.699	.39884	.441	.0304	0.134

TABLE XII

HONOLULU PLANTATION COMPANY

1928 Ripening Experiment—Field 23, Waimalu

Series D Plots—Harvested July 17, 1928

Age of Cane, 22.2 Months

Seventy-seven days since last irrigation

Plot No.	Area	T.C.P.A.	Brix	Pol.	Purity	App. Q.R.	T.S.P.A.	T.S.P.A. P.M.	Glucose	% P_2O_5	% K_2O
D 1	.040889	54.02	21.79	20.00	91.79	6.50	8.31	.3743	.383	.030	0.105
D 2	.042194	54.53	21.69	19.76	91.10	6.62	8.24	.3712	.354	.030	0.135
D 3	.037669	54.85	21.59	19.78	91.62	6.58	8.34	.3757	.398	.028	0.107
D 4	.036329	54.02	22.05	20.24	91.79	6.43	8.40	.3784	.368	.031	0.109
D 5	.031637	56.38	21.15	19.09	90.26	6.89	8.18	.3685	.482	.036	0.122
D 6	.034623	73.03	21.15	19.09	90.26	6.89	10.60	.4775	.488	.033	0.127
D 7	.039433	46.39	21.29	19.26	90.47	6.82	6.80	.3063	.420	.044	0.150
D 8	.041591	54.80	21.30	19.40	91.08	6.74	8.13	.3662	.408	.032	0.136
D 9	.037307	53.12	20.84	18.69	89.68	7.07	7.51	.3383	.550	.026	0.123
D 10	.035999	55.24	21.75	19.88	91.40	6.56	8.42	.3793	.351	.030	0.128
Ave.	.037767	55.64	21.46	19.52	90.95	6.71	8.29	.3736	.420	.032	0.124

TABLE XIII
HONOLULU PLANTATION COMPANY
1928 Ripening Experiment—Field 23, Waimalu
Series E Plots—Harvested July 30, 1928
Age of Cane, 22.6 Months
Ninety days since last irrigation

Plot No.	Area	T.C.P.A.	Brix	Pol.	Purity	App. Q.R.	T.S.P.A.	T.S.P.A. P.M.	Glucose	% P_2O_5	% K_2O
E 1	.036880	55.50	21.67	19.56	90.26	6.73	8.25	.36504	.581	.028	0.112
E 2	.038976	59.54	22.10	20.25	91.63	6.43	9.26	.40973	.312	.032	0.168
E 3	.037345	52.47	21.95	20.05	91.34	6.51	8.06	.35663	.467	.028	0.129
E 4	.036548	53.08	21.73	19.79	91.07	6.61	8.03	.35530	.519	.033	0.110
E 5	.0285570	58.08	21.35	19.40	90.87	6.75	8.60	.38053	.541	.028	0.117
E 6	.035746	61.26	21.07	19.02	90.27	6.92	8.85	.39159	.602	.028	0.116
E 7	.039257	57.32	21.62	19.72	91.21	6.62	8.66	.38318	.441	.033	0.119
E 8	.036878	60.10	21.78	19.88	91.28	6.57	9.15	.40486	.384	.033	0.167
E 9	.0383370	72.87	21.03	19.04	90.54	6.90	10.56	.46725	.480	.034	0.167
E 10	.035023	71.32	20.75	18.67	89.83	7.08	10.07	.44557	.692	.022	0.118
Ave.	.0363547	60.15	21.51	19.54	90.83	6.71	8.95	.39597	.502	.0299	0.132

TABLE XIV
HONOLULU PLANTATION COMPANY
1928 Cane Ripening Experiment—Field 23, Waimalu
Series F Plots—Harvested August 13, 1928
Age of Cane, 23.06 Months
One hundred and four days since last irrigation

Plot No.	Area	T.C.P.A.	Brix	Pol.	Purity	App. Q.R.	T.S.P.A.	T.S.P.A. P.M.	Glucose	% P_2O_5	% K_2O
F 1	.037997	63.17	21.66	19.45	89.80	6.79	9.30	.4033	.653	.028	0.129
F 2	.039432	45.59	22.36	20.40	91.24	6.40	7.12	.3088	.328	.028	0.128
F 3	.039477	47.05	22.26	20.16	90.57	6.51	7.23	.3135	.471	.032	0.118
F 4	.029694	67.77	21.08	18.71	88.76	7.11	9.53	.4133	.629	.036	0.165
F 5	.040691	59.10	21.68	19.44	89.67	6.80	8.69	.3768	.610	.028	0.102
F 6	.035349	60.19	21.28	19.21	90.27	6.85	8.79	.3812	.502	.031	0.151
F 7	.022190	68.95	21.03	18.71	88.97	7.10	9.71	.4211	.631	.031	0.152
F 8	.037629	53.88	22.03	19.81	89.92	6.66	8.09	.3508	.487	.031	0.168
F 9	.035856	60.87	20.53	18.18	88.55	7.26	8.38	.3634	.705	.026	0.139
F 10	.034808	66.51	21.76	19.56	89.89	6.75	9.85	.4271	.652	.027	0.098
Ave.	.035312	59.31	21.57	19.36	89.76	6.82	8.67	.3759	.567	.0298	0.135

TABLE XV
HONOLULU PLANTATION COMPANY
1928 Ripening Experiment—Field 23, Waimalu
Series G Plots—Harvested August 27, 1928
Age of Cane, 23.53 Months
One hundred and eighteen days since last irrigation

Plot No.	Area	T.C.P.A.	Brix	Pol.	Purity	App. Q.R.	T.S.P.A.	T.S.P.A. P.M.	Glucose	% P_2O_5	% K_2O
G 1	.043745	52.12	22.30	19.87	89.10	6.68	7.801	.3315	.632	.030	0.145
G 2	.039090	47.03	22.39	20.32	90.76	6.45	7.291	.3099	.498	.027	0.194
G 3	.035690	43.84	22.09	19.96	90.36	6.59	6.653	.2827	.562	.036	0.120
G 4	.039691	57.32	22.13	19.88	89.83	6.64	8.632	.3669	.544	.028	0.150
G 5	.028863	59.62	22.26	19.89	89.35	6.66	8.952	.3805	.606	.030	0.110
G 6	.034190	64.02	20.73	17.78	85.77	7.68	8.336	.3543	1.010	.026	0.133
G 7	.036171	51.29	21.73	19.41	89.32	6.83	7.510	.3192	.652	.032	0.140
G 8	.031062	55.40	21.43	18.71	87.31	7.20	7.694	.3249	1.018	.052	0.188
G 9	.027842	62.75	22.13	19.72	89.11	6.73	9.324	.3963	.601	.031	0.143
G 10	.040900	71.47	20.84	18.33	87.96	7.31	9.778	.4156	.775	.028	0.131
Ave.	.035724	56.49	21.80	19.39	88.89	6.88	8.197	.3482	.6898	.032	0.145

Nitrate Nitrogen

The average nitrate nitrogen in parts per million of dry soil is summarized below for each harvest:

Date of Sample	Series	First Foot	Second Foot	Third Foot	Average
May 25	A	17.0	16.2	15.5	16.2
June 14	B	20.5	19.6	17.3	19.1
July 5	C	14.2	12.9	12.0	13.0
July 17	D	13.8	10.7	10.3	11.6
July 30	E	13.9	12.5	11.2	12.5
Aug. 14	F	17.3	14.6	12.5	14.8
Aug. 27	G	15.9	14.9	14.3	15.0

We do not know enough as yet about the relation between nitrate nitrogen at harvest time and maximum sugar yields to enable us to arrive at any definite conclusion in regard to the above data.

But we desire to point out some interesting possible relations. We note that the period of lowest nitrate nitrogen was from July 5 to July 30. This was also the period of maximum sugar yields. After July 30, when the yields began to diminish, the nitrates in the soil again increased. Does this increase in nitrates mark the beginning of deterioration? If this is really the case for best results the field should be harvested before the increase is appreciable. It is possible that by frequent sampling one might be able to detect the beginning of the low nitrate period. This would correspond to the beginning of the interval of optimum yield. in this particular case July 5 to 30. This is, of course, purely speculative. We plan to follow up this phase of the work at Waipio this year if time permits.

However, our best measure of the ripeness of cane will probably continue to be analyses of samples of the cane itself.

Soil Moisture

During the interval between the last irrigation and last harvesting date, 5.33 inches of rain fell. Although a great deal of this was in small amounts, it certainly prevented the soil from drying out as fast as it would have, had more arid conditions prevailed.

The soil samples were taken immediately after the cane was cut. In one case, the July 14 harvest, it rained during the harvesting of the plots. So the figures for this date are not truly representative. The others are normal.

The soil moisture declined rather rapidly to the wilting point, then increased somewhat, due to a series of showers, finally declining once more to the wilting point.

Glucose

The juices had the least glucose from about 70 to 85 days after the last irrigation, from then on there was a steady increase in the glucose content.

Phosphoric acid and potash were determined in the juices after each harvest. The first samples, 25 days after irrigation, showed somewhat lower phosphates and potash than the succeeding ones, which remained constant to the end of the period.

Effect of Ripening Process On Per Cent Fiber In Cane

It seems reasonable to expect that as the cane is dried off during the ripening period the percentage of moisture in the cane, and therefore also the percentage of juice, will decrease, with a consequent increase in fiber. We had no evidence, however, as to whether this trend is very slight, or whether it is marked enough to play an important part in the sugar yield.

The official method for determining fiber is of questionable value in a study of this sort, since the sampling error introduced when a few sticks of cane are allowed to represent a carload may be large. For this reason the following procedure was adopted. A running sample of the finely shredded cane was collected as it came through the shredder. (No juice had been extracted). This was thoroughly mixed, and moisture was determined on a subsample of 500 grams. It is, of course, much easier to draw a representative sample of a carload of cane as it comes from the shredder than when it is still in the form of sticks.

The percentage of moisture in the cane having been determined, per cent fiber was arrived at as follows: Knowing the per cent solids (Brix) in crusher juice, the per cent solids in normal juice was determined by applying the correction factor .9276 (the plantation average for the period under consideration). One hundred per cent solids gives us per cent moisture in the juice. Having thus determined the ratio between solids and moisture, the per cent solids remaining in the dry material of the moisture determination samples may be calculated, the per cent moisture being known. Subtracting from the total dry material the per cent solids thus calculated gives per cent fiber.

This method is, of course, workable only in the case of installations having a shredder which cuts up the cane finely without extracting any juice.

The data are given in Table XVI. They indicate that fiber increases somewhat as the ripening progresses but that this increase does not reach very great proportions. While there is a difference of almost 2 per cent between the B series, which had the lowest, and the D series, which had the highest fiber, all the series taken together show that the difference in fiber between unripe and ripe cane in this experiment is around 1 per cent.

TABLE XVI

TREND OF FIBER IN CANE

Plot Series	Per Cent Moisture in Cane	Calculated Brix of Normal Juice	Per Cent Solids in Cane	Per Cent Fiber (by difference)	Days Since Final Irrigation
A	70.14	18.17	15.8	14.3	25
B	69.57	18.95	16.3	14.2	44
C	68.53	20.08	17.2	14.3	65
D	67.18	19.90	16.7	16.1	77
E	67.45	19.95	16.8	15.7	90
F	68.19	20.00	17.0	14.8	104
G	67.89	20.22	17.2	14.9	118

TABLE XVII
SUMMARY

Plot Series	T.C.P.A.	Brix	Pol.	Pur.	Q.R.	T.S.P.A.	T.S.P.A. P.M.	Glucose	% P_2O_5	% K_2O	Per Cent Fiber	Days Since Final Irrigation
A	55.0	19.59	17.63	89.98	7.50	7.32	.363	0.45	.025	0.112	14.3	25
B	57.9	20.43	18.37	89.91	7.20	8.03	.381	0.52	.028	0.130	14.2	44
C	58.2	21.65	19.75	91.20	6.68	8.70	.399	0.44	.030	0.134	14.3	65
D	55.6	21.46	19.52	90.95	6.71	8.29	.374	0.42	.032	0.124	16.1	77
E	60.1	21.51	19.54	90.83	6.71	8.95	.396	0.50	.030	0.132	15.7	90
F	59.3	21.57	19.36	89.76	6.82	8.67	.376	0.57	.030	0.135	14.8	104
G	56.5	21.80	19.39	88.89	6.88	8.20	.348	0.69	.032	0.145	14.9	118

The sugar per acre figures given in the charts and tables are based on quality ratio, which assumes a constant fiber content. If these figures were corrected for the increase in fiber the last four harvestings would show a yield of around 1 per cent less, on the average, than given in the charts and tables. This is a small difference and does not change the trend of the curves perceptibly. If the results of this experiment are a fair sample, we may say that within a single variety fiber does not vary greatly enough to be a material factor in sugar yield even when comparing unripe with ripe cane. If the cane were dried off to the point of dying, we might, however, find a wider difference.

Summary

Honolulu Plantation Company, with the cooperation of the chemistry, sugar technology and agricultural departments of this Station, has carried out an experiment to obtain information as to the trend of sugar yield during the ripening period.

Field Waimalu 23 was selected for the experiment. A series of ten plots distributed uniformly over the field was harvested at the beginning of the ripening period. twenty-five days after the final irrigation. A second series was harvested three weeks later, and so on. In all, seven series covering a period of four months were harvested.

At each harvesting, the following determinations were made for each plot, cane yield, Brix, polarization and purity, of the crusher juice. From these the quality ratio, yield of tons sugar per acre and tons sugar per acre per month were calculated. Per cent glucose, P_2O_5 and K_2O in juice and per cent fiber in cane were also determined. Soil samples from the first-, second- and third-foot depths were also taken for each plot and their moisture and nitrate nitrogen contents determined.

The trends of the different values were as follows:

1. Yield of cane per acre increased slightly up to 44 days and remained practically constant thereafter.
2. Brix increased at first rather rapidly and thereafter more slowly.
3. Polarization increased rapidly up to 65 days, after which it declined gradually.
4. Purity improved up to 65 days, thereafter holding its level fairly constant to 90 days, when it began to decline.

5. Yield of sugar per acre increased rapidly up to 65 days, and more slowly up to 90 days, after which it declined.

6. Yield of sugar per acre per month increased rapidly up to 65 days after which it declined, at first gradually, then rapidly.

7. Per cent moisture in cane declined slightly and gradually.

8. Per cent fiber in cane increased as ripening progressed, somewhat erratically, however, due probably to experimental error.

9. Soil moisture declined to the wilting point, then rose again as a result of showers and finally declined once more to the wilting point.

10. Nitrate nitrogen in the soil first declined and then increased.

11. P_2O_5 and K_2O in the juice showed a slight and gradual increase, associated possibly with the slight increase in concentration of cell sap due to drying out.

The above results are shown graphically in Fig. 2.

It is concluded that under the conditions of the experiment the greatest returns in terms of sugar per acre per month are realized when the cane is harvested within 60 to 90 days after the final irrigation. Over ripening may result in loss of sugar, loss of growing time for the next crop, and injury to ratoons.

The Sugar Yields in a Typical Irrigated Plantation of Hawaii—The Ewa Plantation Company

Being Mainly an Analysis of the Influence of Weather Conditions on Sugar Production

By U. K. Das

Introduction

The succession of record sugar crops in these Islands has stimulated an inquiry into their probable causes. Are these causes permanent or only temporary? In other words, are we going to maintain, if not improve upon, these high yields in the future, or is it likely that the yields may fall below the new level?

In the history of the past few years several factors stand out prominently as having some influence on these record yields:—(a) the spread of H 109 cane, (b) the wider application of scientific knowledge, both in the field and the factory, (c) steady labor conditions, (d) freedom from diseases and pests, (e) warmer weather. The first four have received favorable comment and considerable attention, but it appears that the weather has been more or less ignored, due, no doubt, to the absence of definite knowledge of the relation of weather conditions to sugar yields in these Islands. Also, while we are easily persuaded that it is the bad weather that decreases our yields, we are not so ready to believe that it may again be the good weather that at least partially increases them.

Broadly speaking it is the climate of a place that determines not only the nature of the crop that can be grown but also the profitable limits of its production. It is due to the climate that while Cuba and Java produce a crop in little over one year, it takes about two years to do the same in Hawaii. Now we may consider climate as the average weather over a long period of years. In this sense the climate of a place may vary considerably, if only temporarily. Thus it is possible for Hawaii to be transported for a period to a warmer and sunnier climate with better advantages for sugar production; or to a cooler climate. Then, in spite of our efforts, sugar yield may fall below the normal.

It is the object of the present series of weather studies to show that there have been in the past appreciable changes in the climatic conditions of these Islands and that the yield of sugar has been very definitely influenced by them. It is doubtful if the excellent yields of recent years could have been obtained if the weather had been less favorable.

The Present Study

In a previous paper(2), it has been shown that even in Hawaii the climatic conditions change enough from year to year to cause definite fluctuations in the yields of unirrigated plantations. The question now arises: Are the climatic influences as great in the case of the irrigated plantations which are practically independent of nature for their moisture supply? In other words, does there exist a definite relation between one or more of the weather elements, such as sunlight, temperature, precipitation, etc., and sugar yield? Do variations in any or all of these elements cause a corresponding variation in the production per acre? To answer these questions we have, in the present paper, attempted an analysis of the sugar yields of a typical irrigated plantation on Oahu, namely, the Ewa Plantation Company.

General Considerations

Before proceeding to investigate the significance of climatic changes on sugar yields, let us consider briefly the factors in sugar production. Sugar, we shall say, is made in the field in the cane and the major factors in cane production are—(a) plant food, (b) moisture, (c) sunlight and (d) warmth. All these factors, except the last two, are capable of variation independently of each other and any of these by reaching a limiting value can limit the production. Thus, if plant food is lacking no amount of moisture, sunlight and warmth will produce a crop. The same is true of each of the other factors. For maximum results, then, there must be a happy combination of all these factors. It amounts to the same thing as saying that for a given set of values for any of the three factors, there will be a particular value of the fourth that will give maximum results. This point is of fundamental importance in practical agriculture, for it suggests that as the amount of sunlight or warmth varies the amount of moisture or the amount of plant food may have to be varied to obtain the greatest return.

Also, there are strong evidences in support of the theory that during the various stages of its growth and development, the sugar cane plant requires varying amounts of the element such as plant food, moisture, sunlight, warmth, etc. De-

priving the plant of the required optimum at any period may so far disturb its normal growth that all late remedies may prove partially or wholly fruitless. To illustrate the point—a cane field recently started requires plenty of nitrogen for best development. If this nitrogen is withheld for the first 8 or 10 months, then an extra dose of nitrogen at a later stage will not restore all of the lost growth or do nearly as much good as a less amount applied when the cane really needed it. This means that with respect to each of the factors that promote growth, there is what we may term, an "optimum time of application." In other words, to a sugar cane crop the quantities of moisture, warmth, etc., that come at certain critical periods are of more importance than the total quantities during its entire lifetime.

Soil and Climate

The Ewa Plantation Company lies on the leeward side of the island of Oahu. The total area in cultivation is about 7600 acres. Of this about 40 per cent is good, well-drained soil and the rest either poorly drained or coral (see Appendix A).

The mean annual temperature is 73.9° and the mean annual rainfall 20.64 inches. In Tables I and II are given respectively the records of temperature and rainfall at Ewa since 1903. The monthly average temperature and rainfall are shown graphically in Fig. 1. With an annual rainfall of only 21 inches, and over half of this amount falling within the three cool months of January, February and March, the lands at Ewa are definitely the semi-arid type. In other words, at Ewa water is the greatest necessity for profitable crop production. It is also seen from this chart that at Ewa the winter proper is during the months of January, February and March; and that the month of December is warmer than March.

Ewa Plantation Co.
Monthly average rainfall and monthly mean temperature
(1903 - 1917)

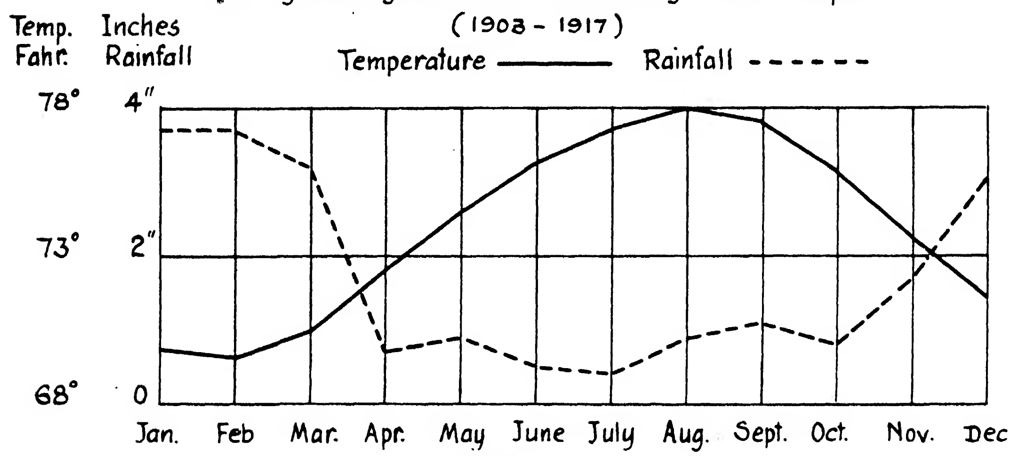


Fig. 1

Ewa Plantation Co.
Comparative yields of Lahaina Yellow Caledonia and D 1135
from 1912-1917 inclusive

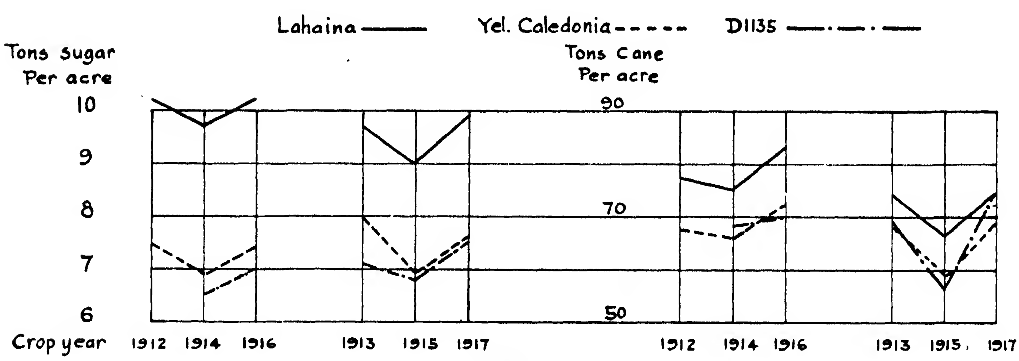


Fig. 2

Ewa Plantation Co.
Curves comparing the yield of cane and sugar from selected fields of Lahaina with the yields from the whole plantation

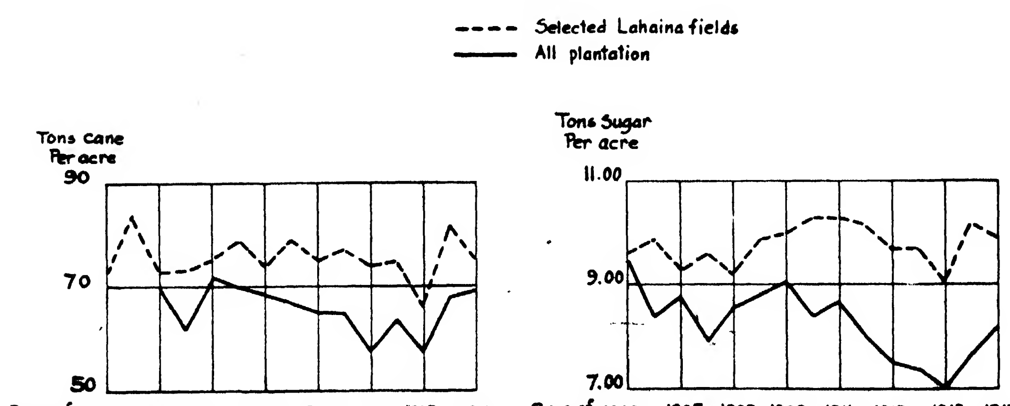


Fig. 3

TABLE I

EWA PLANTATION COMPANY

RECORDS OF MONTHLY MEAN TEMPERATURE

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1903	69.5	68.0	68.0	73.0	75.0	76.0	78.5	78.8	77.8	75.5	73.4	72.5	73.8
1904	71.7	69.3	70.0	72.0	73.1	74.8	76.1	76.9	76.7	74.6	71.1	70.8	73.0
1905	64.7	66.4	67.4	70.2	72.2	73.9	75.6	76.9	75.6	73.6	72.4	68.6	71.4
1906	67.7	68.0	67.4	73.7	74.4	77.5	78.0	78.7	78.2	77.4	74.4	72.6	74.0
1907	72.3	71.1	70.8	71.2	74.8	76.8	77.3	78.7	78.6	76.3	74.3	72.7	74.6
1908	70.2	71.0	71.8	72.3	74.8	75.2	76.0	77.0	76.2	74.9	72.5	71.2	73.6
1909	69.2	69.8	70.6	71.7	74.4	76.9	77.4	77.2	77.0	76.0	73.8	71.8	73.8
1910	69.9	69.4	72.0	72.2	73.6	75.6	76.5	77.0	76.5	75.3	73.8	70.6	73.5
1911	69.7	69.8	71.0	73.7	75.0	76.4	77.8	79.2	77.8	75.1	73.6	72.0	74.3
1912	70.2	70.6	69.6	73.3	74.8	76.0	77.6	78.6	78.3	77.5	74.0	73.6	74.5
1913	71.5	69.6	72.1	74.0	74.6	76.4	77.9	78.7	78.4	77.4	75.0	71.6	74.8
1914	69.2	70.2	70.4	72.8	74.6	77.0	78.3	79.8	79.0	77.2	74.1	70.2	74.4
1915	69.3	69.2	70.8	72.1	75.4	77.8	78.6	79.8	78.8	77.0	74.2	72.2	74.6
1916	70.2	71.4	72.2	73.6	74.6	75.4	76.3	75.8	76.0	75.4	73.9	71.1	73.8
1917	69.3	69.2	71.2	72.3	73.9	75.6	76.6	77.2	77.0	75.6	73.9	71.9	73.6
1918	71.0	70.4	70.0	71.0	73.1	75.4	77.8	77.8	77.0	77.3	73.6	71.6	73.8
1919	68.9	70.6	70.4	72.7	74.1	76.3	77.5	78.4	76.6	75.7	73.4	71.1	73.8
1920	69.5	70.4	71.4	72.5	74.0	74.7	77.2	77.9	77.8	76.4	73.1	71.6	73.9
1921	70.7	70.4	71.2	72.8	73.4	77.2	77.1	77.1	76.8	74.4	72.7	71.6	73.8
1922	70.2	69.6	70.8	72.9	73.1	74.8	76.3	76.5	76.2	74.8	72.6	70.8	73.2
1923	70.7	68.2	70.4	72.6	74.2	75.4	77.1	77.5	77.1	75.8	73.2	70.9	73.6
1924	67.4	70.2	70.0	71.0	73.5	74.2	76.0	76.0	75.8	75.0	72.2	70.6	72.6
1925	71.8	71.6	70.6	71.4	72.8	74.2	75.4	76.0	75.1	74.4	72.8	71.9	73.2
1926	70.9	71.1	71.7	70.9	75.6	76.4	77.8	77.8	77.9	76.2	73.3	73.0	74.4
1927	71.1	71.0	72.6	73.4	75.0	76.6	74.7	77.4	77.2	75.5	73.9	71.8	
1928	70.2	69.4											
Average 1903-1917													
	69.8	69.5	70.4	72.5	74.4	76.1	77.2	78.0	77.5	75.9	73.6	71.6	73.9

TABLE II

EWA PLANTATION COMPANY
RECORDS OF MONTHLY PRECIPITATION

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1903	1.39	1.39	1.51	1.12	0.89	0.98	0.00	0.18	1.83	1.76	2.17	0.18	13.40
1904	1.32	25.21	6.79	0.49	0.09	0.72	0.55	1.02	0.98	1.97	3.05	1.95	44.14
1905	0.20	0.00	0.56	0.21	0.16	0.22	0.08	1.94	0.74	0.71	1.03	1.34	7.19
1906	3.23	0.00	1.62	0.02	0.88	0.09	0.40	0.21	0.44	0.35	5.34	10.09	22.67
1907	13.77	4.29	2.38	0.04	3.04	0.31	0.96	0.52	0.63	0.38	0.30	2.62	29.24
1908	0.03	1.55	9.26	0.06	0.23	0.14	0.00	0.53	1.12	0.20	0.61	0.36	14.09
1909	3.10	4.93	3.04	0.44	0.10	0.30	0.16	0.09	0.25	0.56	0.07	4.55	17.59
1910	1.18	0.51	0.39	0.41	0.12	0.59	0.63	1.25	3.28	0.35	3.21	3.24	15.16
1911	3.11	6.50	1.44	0.39	0.43	0.32	0.40	0.39	1.07	0.89	0.21	1.42	16.57
1912	0.55	2.07	0.32	1.20	0.22	0.04	0.09	0.40	0.02	0.93	1.16	1.20	8.20
1913	0.43	0.83	0.67	0.50	3.08	3.01	0.53	3.13	1.04	1.05	1.47	0.08	15.82
1914	1.65	1.32	4.60	0.85	1.08	0.29	0.51	0.27	2.12	0.00	1.21	2.74	16.64
1915	0.21	0.21	0.45	1.28	0.35	0.24	0.86	0.02	1.87	0.72	6.52	7.67	20.40
1916	16.32	4.82	3.58	1.66	0.56	0.05	0.48	1.60	0.55	1.57	0.55	3.49	35.23
1917	9.58	2.15	10.93	1.24	1.79	0.16	0.42	1.55	1.05	0.87	1.39	5.19	36.32
1918	6.94	3.35	4.68	7.63	0.24	0.37	0.02	1.77	0.79	0.44	6.38	3.22	35.83
1919	0.60	0.00	0.40	0.37	0.46	0.49	0.16	0.10	0.99	2.60	1.34	1.04	8.55
1920	4.65	0.37	2.49	0.72	0.60	0.67	0.48	0.40	0.00	0.27	0.86	12.73	24.24
1921	7.22	1.67	0.55	0.21	0.26	0.00	0.21	0.25	0.40	3.16	0.20	5.65	19.78
1922	3.06	0.32	1.82	0.08	0.40	0.05	0.10	0.00	1.20	0.55	0.75	0.23	8.56
1923	6.17	6.17	3.62	1.99	0.00	0.00	0.00	0.00	0.23	0.23	0.00	8.08	26.44
1924	0.00	1.32	1.63	10.27	0.19	0.00	0.45	0.20	0.46	0.83	1.13	4.64	21.12
1925	0.12	0.28	2.72	0.40	0.00	0.08	0.00	0.00	0.40	1.87	1.20	2.70	9.77
1926	0.72	0.52	0.73	1.07	0.11	3.23	0.76	0.74	0.32	3.28	0.21	0.92	12.61
1927	1.82	3.17	4.94	2.21	2.74	0.28	0.33	0.08	1.30	0.49	2.52	21.37	41.25
Average 1903-1927													
	3.74	3.72	3.17	.66	.87	.50	.40	.87	1.13	.82	1.69	3.07	20.64

TABLE III

EWA PLANTATION COMPANY

AREA, VARIETY OF CANE, YIELD OF SUGAR

Crop year	Area in acres	Predominant variety	Tons Total Sugar	Tons sugar per acre
1903	3485	Lahaina	33,213	9.54
1904	3724	,,	31,185	8.37
1905	3482	,,	30,752	8.83
1906	3719	,,	29,479	7.93
1907	3719	,,	32,020	8.62
1908	3843	,,	33,769	8.79
1909	3732	,,	33,909	9.08
1910	3754	,,	31,490	8.39
1911	3987	,,	34,397	8.63
1912	3916	,,	31,448	8.03
1913	3937	Lahaina, Y. C. & D 1135	29,439	7.48
1914	4076	,,	29,933	7.36
1915	4177	,,	29,295	7.01
1916	4173	,,	32,045	7.68
1917	4249	,,	34,748	8.18
1918	4082	Lahaina & H 109	33,840	8.29
1919	4191	,,	37,405	8.93
1920	3885	H 109	33,854	8.71
1921	3660	,,	29,271	7.99
1922	4299	,,	39,672	9.23
1923	3996	,,	32,485	8.13
1924	4437	,,	46,162	10.40
1925	4281	,,	50,822	11.87
1926	4651	,,	51,168	11.00
1927	4493	,,	50,518	11.24
1928	4693	,,	54,000	11.50

Sugar Yields At Ewa

The total yield, the area, variety of cane, and the yield of sugar per acre from year to year are given in Table III. The yield per acre is presented graphically in Fig. 3. A study of this figure shows that at Ewa not only the yields have fluctuated considerably from year to year but also there have been fairly well-defined periods of high and low yields. In the annual reports of the plantation, the causes of this periodic fluctuation are given as follows:

(1) Years 1904-1907—decreased yields due to leafhopper damage.
(2) Years 1912-1915—decreased yields due to the failure of Lahaina.
(3) Years 1916-1919—increased yields due to the introduction of the new variety H 109.
(4) Years 1920-1923—low yield attributed to labor strikes.
(5) Years 1924-1928—record increase in yields due to the improved variety of cane—namely, H 109, better methods in the field and factory, steady labor conditions, etc.

It is of interest that while passing mention has been made once or twice of adverse weather such as drought or the extremely cool temperature of 1905, the weather conditions in general have never been recognized to have any significant association with these high or low yields. Yet, a study of the temperature and rainfall records shows that the years 1904, 1905 and part of 1906 were exceedingly cool; that the summer months of 1912, 1913, 1914 and 1915 had the highest mean temperatures on record; that from 1908-1914 the annual rainfall was considerably below the normal. Now knowing, as a result of innumerable experiments and also cane growth measurements, that there exist very definite relations between temperature or moisture and growth, we would expect these great fluctuations in temperature or moisture conditions to have influence on sugar yields at Ewa. Our problem, then, is to determine which of the fluctuations in yield could reasonably be regarded as due to adverse growing conditions and which due to accidental circumstances, such as the outbreak of a disease.

Years 1904-1907

This period furnishes additional evidence of the fact that weather changes in a mild climate like ours are generally regarded as of little importance, for, even the very progressive management of this plantation makes no mention of the low temperatures of 1904-1906, in giving leafhopper damages as the only known reason "for the gradual fall in yields from 1903-1906 and the sharp rise in 1907".* Yet, a study shows that these low temperatures could have contributed to the magnitude of the losses at Ewa.

At Ewa the years 1904 and 1905 were the coolest in all the 28 years for which temperature data are available. The mean annual temperature in 1905 was only 71.4° compared to the normal of 73.9°. The temperature in the winter months of 1905 averaged about 4° below normal; to be exact, the mean temperature of these months was only 66.1°.

In other words, if we take only the temperatures above the 60° mean to be effective, then, in the year of 1905, there were available for sugar cane growth 11.4x365 day-degrees, compared to the normal warmth of 13.9x365 day-degrees. That means a reduction of 17 per cent of available warmth in the whole year. In certain particular seasons of 1904 and 1905, this reduction in warmth was even greater. Cane growth being a definite function of warmth, it is our belief that in the years 1904, 1905 and part of 1906, temperature was a limiting factor to normal sugar production.

We have, therefore, included the years 1904-1907 in the present study in the belief that these years reflect, not in magnitude but only in trend, the influences of weather conditions.

Years 1912-1915

That on certain places of these Islands Lahaina cane has failed to make normal growth no one will deny. Far less will any one doubt that the continued cultivation of this failing variety had materially decreased the yield of sugar at Ewa.

* Annual Reports of the Ewa Plantation Company, 1908.

The exact nature of this "Lahaina failure" or "Lahaina disease"—or the more modern term "root rot complex"—is not yet definitely understood. How are we then, in the absence of definite knowledge, going to estimate the losses at Ewa due to this disease alone? We decided to do it in an indirect manner.

With the beginning of the disease at Ewa, the fields in which Lahaina was failing were replanted with other varieties—such as Yellow Caledonia and D 1135. By the year 1915, when the Lahaina disease was considered to be at its worst, Yellow Caledonia and D 1135 constituted the major part of the crop. But there was still about 25 per cent of the total area in which Lahaina cane was being grown. These fields were yielding fairly normal crops and they continued to grow Lahaina almost up to 1921 and 1922. It therefore suggested to us that if we took the yield from this small group of fields only, then we would have eliminated, at least to a large extent, the influence of the Lahaina disease. Then the same yields would also give us a pretty good idea of the average yield at Ewa for those years. Furthermore, we decided to study the yields of Yellow Caledonia and D 1135 over this period of years to see if the yields from these varieties also showed the same fluctuations as the yields from Lahaina cane only. In case we found that the fluctuations in yield from all the varieties were identical, then we could be fairly certain that the causes of these fluctuations were not entirely due to the Lahaina disease, for, Yellow Caledonia and D 1135 were known to be immune to this malady.

The results of our investigations are briefly set forth in Table IV and Fig. 2. The details are given in Appendix B. In this table we have compared the yields from a group of selected fields only so as to avoid errors due to the grouping of different fields. In the case of D 1135, however, such careful segregation was not possible due to the comparatively small area in that variety. Also, we have considered the yield of plant and long ratoons only so as to eliminate the extremely variable influence of the small areas in short ratoons.

TABLE IV

COMPARING THE YIELDS OF LAHAINA, YELLOW CALEDONIA AND D 1135 FROM A GROUP OF SELECTED FIELDS ONLY

	Tons cane per acre			Tons sugar per acre		
Crop Year	Lahaina	Y. C.	D 1135	Lahaina	Y. C.	D 1135
1913	74.16	68.2	69.4	9.69	8.03	7.11
1915	66.43	57.5	56.2	9.00	6.90	6.84
1917	74.67	69.1	75.5	9.89	7.62	7.64
1912	76.79	67.4	......	10.16	7.48	......
1914	74.81	65.7	68.0	9.72	6.85	6.45
1916	82.35	72.1	69.5	10.18	7.39	7.01

These results have proved to be more than satisfactory. They have brought out that in 1912, 1913, 1914 and 1915 the fluctuations in yield from the selected Lahaina fields were of the same nature as the fluctuations from the fields of other varieties. In other words, these fluctuations were caused by factors other than the Lahaina disease. The yield from this selected group of Lahaina fields, plants and long ratoons only, were obtained for the period 1903-1917. These results are shown in Table V and Fig. 3.

TABLE V

YIELD OF CANE AND SUGAR IN A SELECTED GROUP OF LAHAINA FIELDS

Crop Year	Tons cane p. a.	Tons sugar p. a.	Crop year	Tons cane p. a.	Tons sugar p. a.
1903	71.58	9.60	1904	84.30	9.89
1905	73.37	9.30	1906	72.49	9.58
1907	75.38	9.19	1908	78.66	9.87
1909	73.82	9.95	1910	79.34	10.34
1911	75.12	10.29	1912	76.79	10.16
1913	74.16	9.69	1914	74.81	9.72
1915	66.43	9.00	1916	82.35	10.18
1916	74.67	9.89			

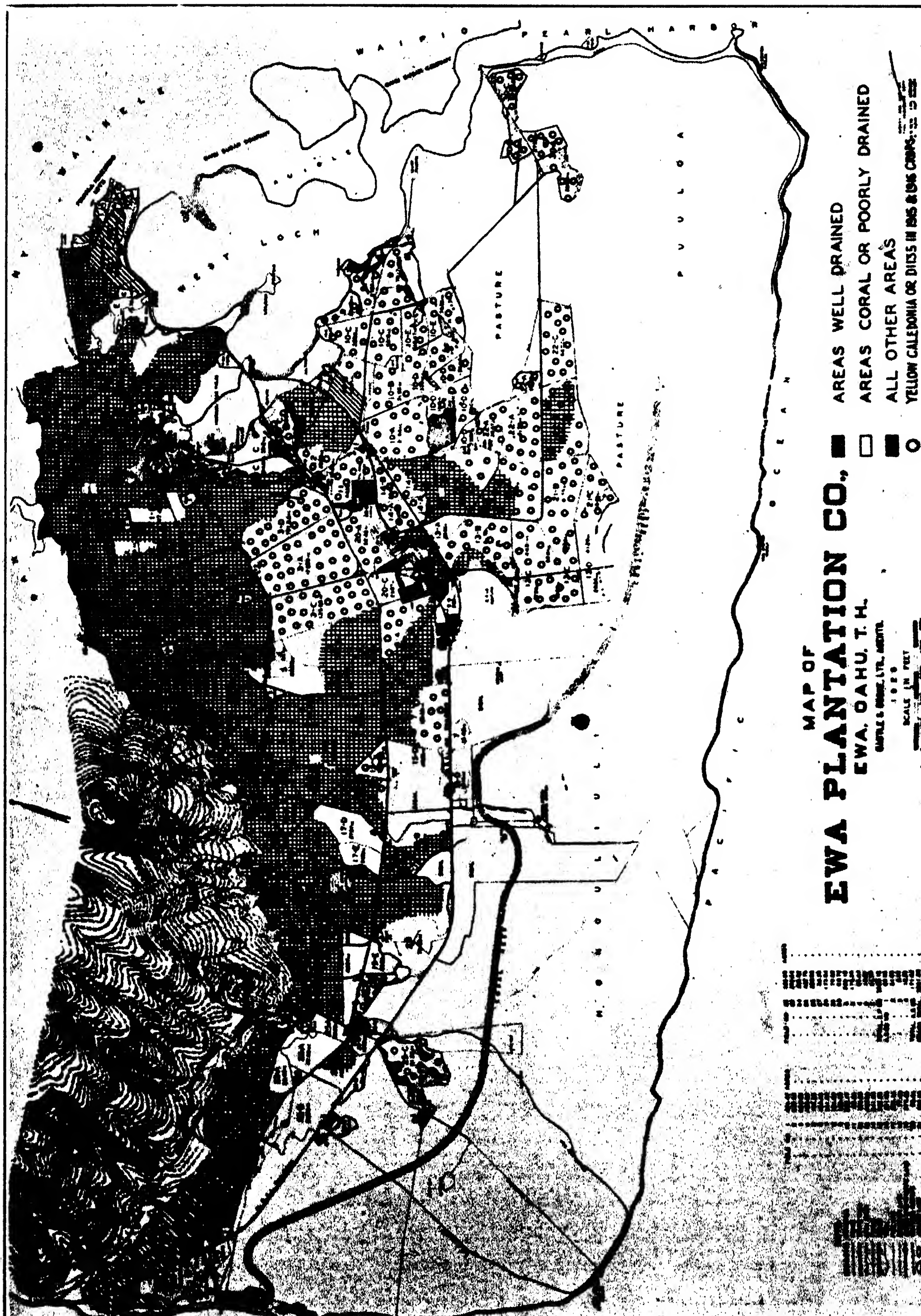
It will be seen from Fig. 3 that the trend of variations in the yield from the selected fields was practically the same as that of the yields from the whole plantation. But the individual variations of these latter yields were very much greater, especially in the period 1912-1915.

This suggests that though the direction of these fluctuations was motivated by extraneous causes, the magnitude of the fluctuations in the latter case might have been caused by Lahaina failure or other factors.

Another point of interest brought out by Fig. 3 is that even as late as 1915, 1916 and 1917, Lahaina was yielding fully as much per acre both in cane tonnage and in sugar as it did at any time previously. This completely explodes the theory that the variety itself was dying out—it was certainly not doing so up to 1917. This agrees with the conclusion reached by Lyon(7) in 1915 that senility was not the cause of Lahaina failure.

Since there was a group of fields in which Lahaina was giving profitable returns long after it had failed in many others, we came to think that the disease itself might have been associated with certain fields and certain soil conditions. Herein is reproduced a map of the Ewa Plantation Company, in which following the classification given in Appendix A, we have segregated the fields with good, well-drained Ewa soil from all the other types of fields. We have also marked the fields that were in Yellow Caledonia or D 1135 in the crop of 1915 or 1916; for, evidently, these were the fields where Lahaina failed initially. A study of the map is of more than passing significance because it shows unmistakably that the Lahaina disease at Ewa was definitely associated with certain soil types. These soils, with few exceptions, are either coral or poorly drained.

The results of this statistical study, therefore, inclines us to believe that at least under Ewa conditions Lahaina disease must have been caused or abetted by some factors in the coral or poorly drained soil, or the disease, if already present, was aggravated by soil conditions characteristic of certain Ewa fields. Lyon(6) in 1909 attributed the trouble at Ewa to poor drainage and accumulations of salts. Again in 1923 the same writer(8) said that in his opinion the disease was not due to fungus but some harmful soil toxin. He also mentioned that the investigators in Java were inclined to think that it was something in the soil. McGeorge(9) found that in some of the fields at Ewa where Lahaina failed to make good growth the salt concentration was high, and that Lahaina made good growth in the same soil after the salt had been leached out. In another report(10)


MAP OF
EWA PLANTATION CO.,
EWA, OAHU, T.H.
AREAS WELL DRAINED
AREAS CORAL OR POORLY DRAINED
ALL OTHER AREAS
PEARL HARBOR
WEST LOCH
PASTURE
PACIFIC OCEAN

McGeorge showed that there was definite relation between the salt content of irrigation water and yield of cane and sugar. It is also an established fact that at Ewa even in the years when Lahaina disease was at its worst, cane made excellent growth following a heavy shower. Not Lahaina alone, but H 109 also suffers from a heavy accumulation of salts. However, from experimental study, McGeorge(10) found that H 109 was very much more tolerant of salt accumulation in the soil than Lahaina. This may explain why H 109 makes good growth in some soils where Lahaina fails.

The weather records of Ewa indicate that undoubtedly in the years 1909-1915, the weather conditions were such as to favor an increasing concentration of salts derived from the irrigation water or possibly from the soil substrata. As has been noted before, from 1908-1914 the annual rainfall at Ewa was very much below normal for each and every year; at the same time the mean summer temperature for the years 1911-1915 was the highest on record. The artesian basin at Ewa reached the lowest level in 1915. It is, therefore, reasonable to think that at Ewa the soil conditions might have contributed to the Lahaina disease and the situation might have been aggravated by the prevailing weather conditions.

To the list of possible causes for the decreased yields in 1913 to 1915 might be added the failure of the substituted varieties—namely, Yellow Caledonia and D 1135—as measured by the standard of yield set by Lahaina.

Years 1920-1923 and 1924-1928

The year 1916 was the turning point for the better in the history of Ewa. This was not due to the introduction of H 109, for this variety did not figure prominently until two or three years later. In the years 1920-1923 decreased yields were certainly due to the scarcity of labor for field operation—this period is omitted entirely from the scope of this study.

It is generally conceded that the years 1924-1928 represent the first crops grown under prime conditions that Ewa has had since the early years of its history. There have been in these years tremendous improvement in all directions and no recognized disturbances of any kind. As this period is totally different from the period 1903-1917, because of the changes in cane variety, field practices, etc., we have not included it in the main study but reserve it for separate treatment in the latter part of this paper.

Materials

Briefly, then, the materials for our immediate study are the yields from a selected group of Lahaina fields for the years 1903-1917. In view of what has been said before, it will be agreed that these yields are a satisfactory index of the average yields for the plantation.

Before seeking the causes of the fluctuations in yields due to weather conditions we have tried to eliminate the influences, if there were any at Ewa, of the varying amounts of plant food—particularly nitrogen.

Table VI gives the history of nitrogen applications at Ewa since 1908. The amounts of nitrogen applied and the yields for the crops are shown in Fig. 4.

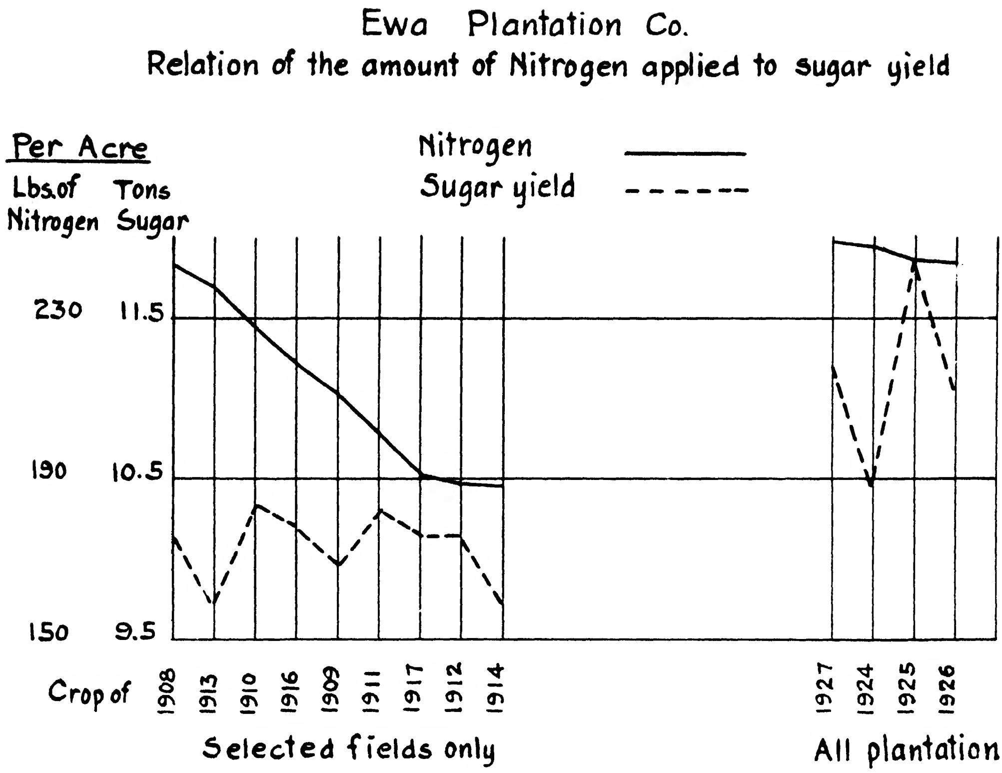


Fig. 4

TABLE VI

POUNDS OF NITROGEN APPLIED PER CROP

Crop of	Pounds nitrogen	Crop of	Pounds nitrogen	Crop of	Pounds nitrogen
1908	243	1913	238	1924	248
1909	212	1914	188	1925	245
1910	228	1915	154	1926	244
1911	201	1916	219	1927	249
1912	189	1917	191	1928	....

Within the limits of variation obtained at Ewa, there does not appear to be any definite relation between pounds of nitrogen and sugar yield. In the year 1915, however, this variation was the greatest and the yield for that year was also very low. This doubtful year has, therefore, been excluded from our study.

Weather data prior to 1903 are not available; therefore, 1903 is eliminated. So after all these segregations and eliminations we have only 13 years for our immediate study, the years 1904-1914, and 1916 and 1917.

Methods

In this study we have employed the statistical methods of correlation. That is, we have tried to discover by mathematical analysis if there exists a definite relation between the presence or absence of such factors as moisture, warmth, sunlight, etc., in certain seasons and the yield of sugar. Such methods of cor-

relation have been successfully used in recent times by Koenig(5) in Mauritius, Tengwall and Van Derzyl(17) in Java; and McDonald(11) in Louisiana. It should be observed that what we are trying to get at is not the mere existence of a mathematical relationship between certain phenomena and sugar yield but the existence of sound biological reasons for the differences in yields from year to year. If the deductions from the mathematical analysis cannot be proved to be biologically sound then these are of no value. It should also be noted that owing to the meagerness of our data the results must be interpreted liberally, nay sympathetically.

Sugar Yield Departures

The yield of cane has not been considered in this report, for we are mainly interested in the amount of sugar produced.

The sugar yields have already been given in Table V. The departures for the odd years and the even years have been obtained respectively from the mean of all the odd years and all the even years as shown in Table VII and Fig. 5. As different groups of fields are harvested in the odd and in the even years, this separate grouping eliminates the possible influence of the group of fields themselves on yield. (It was found later on that our results were not materially affected even if all years were grouped together).

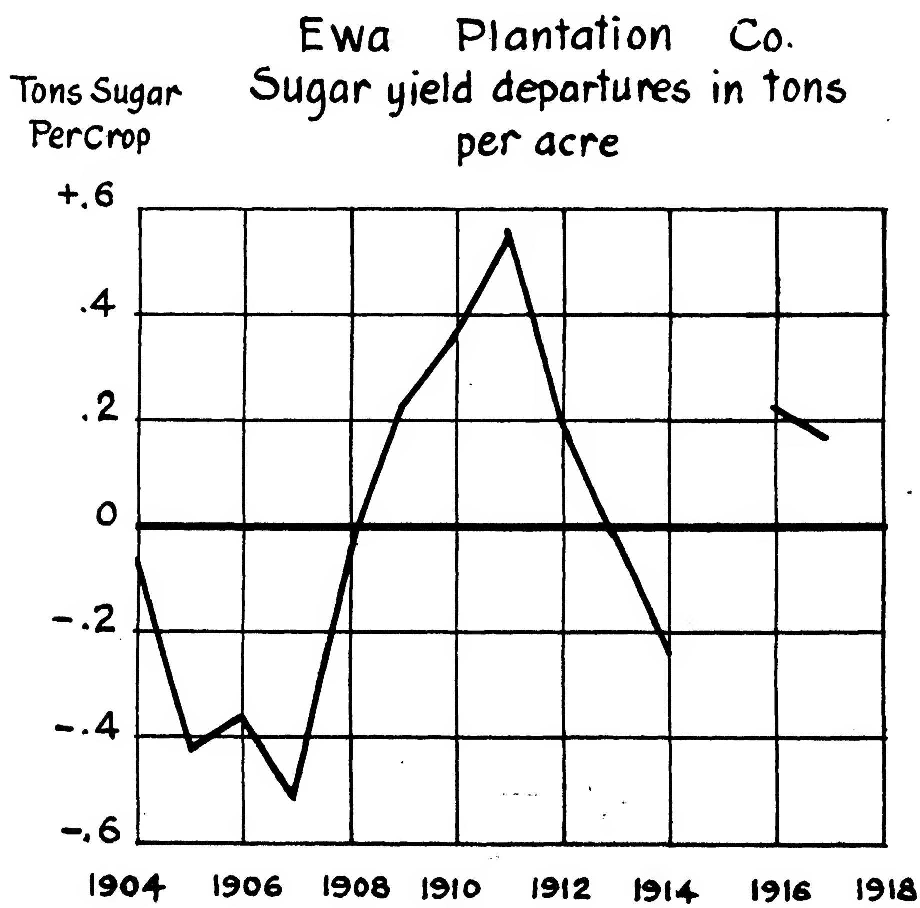


Fig. 5

TABLE VII

SUGAR YIELD DEPARTURES

Year	Yield	Departures	Year	Yield	Departures
1905	9.30	— .42	1904	9.89	— .07
1907	9.19	— .53	1906	9.58	— .36
1909	9.95	+ .23	1908	9.87	— .09
1911	10.29	+ .57	1910	10.34	+ .36
1913	9.69	— .03	1912	10.16	+ .20
1917	9.89	+ .17	1914	9.72	— .24
			1916	10.18	+ .22
Average	9.72			9.96	

We see from Fig. 5 that the two years 1910 and 1911 had the highest positive and the two years 1906 and 1907 the highest negative departures. It is likely that the differences in the supply of moisture and warmth—if these have influenced the yields at all—will be clearly manifested in the history of these years. We propose to treat these years separately a little later.

Total Water and Sugar Yield

At Ewa the moisture supply for the cane is derived almost entirely from irrigation water, the normal yearly rainfall amounting to only 21 inches. Even of this small rainfall, only about half, perhaps less, reaches the ground, the other half being lost by direct evaporation, surface run-off, etc. (This point will be treated more fully as we proceed.) Here, by total water is meant the amount derived from irrigation, plus half rainfall.

The climate of Ewa being of the semi-arid type, on first thought it would appear that here, in general, water might be the limiting factor.

The yield per crop should, therefore, show a fair relation to the total water applied to that crop.

Let us assume that the average crop at Ewa is two years long from January of one year to the January of the year after the next· That is, for 1905 the crop period was from January, 1903, to January, 1905. Let us also assume that of the total amount of water applied each year as irrigation, about one-third of this goes to the young or first year cane and the other two-thirds to the old or second year cane. In other words, let us assume that of the total water used in 1903, one-third went to the crop of 1905 and two-thirds to the crop of 1904. (This assumption is regarded as being fairly sound at least for the period 1903-1917). The results are shown in Table VIII and Fig. 6.

TABLE VIII

TOTAL WATER PER CROP AND YIELD OF SUGAR

Method—crop of 1905

Total water=(1/3 of water, 1903) + (2/3 of water, 1904) + (½ rainfall 1903 and 1904).

Crop of	Total water Ac. In.	% of average	Sugar yield T.S.P.A.	% of average	Crop of	Total water Ac. In.	% of average	Sugar yield T.S.P.A.	% of average
1905	192.76	93	9.30	96	1906	202.57	98	9.58	96
1907	199.05	96	9.19	95	1908	191.03	92	9.87	99
1909	205.91	99	9.95	102	1910	218.59	106	10.34	104
1911	218.59	106	10.29	106	1912	211.69	102	10.16	102
1913	211.69	102	9.69	100	1914	202.42	98	9.72	97
1917	213.88	103	9.89	102	1916	215.09	104	10.18	102
Avg.	206.98		9.72		Avg.	206.90		9.98	

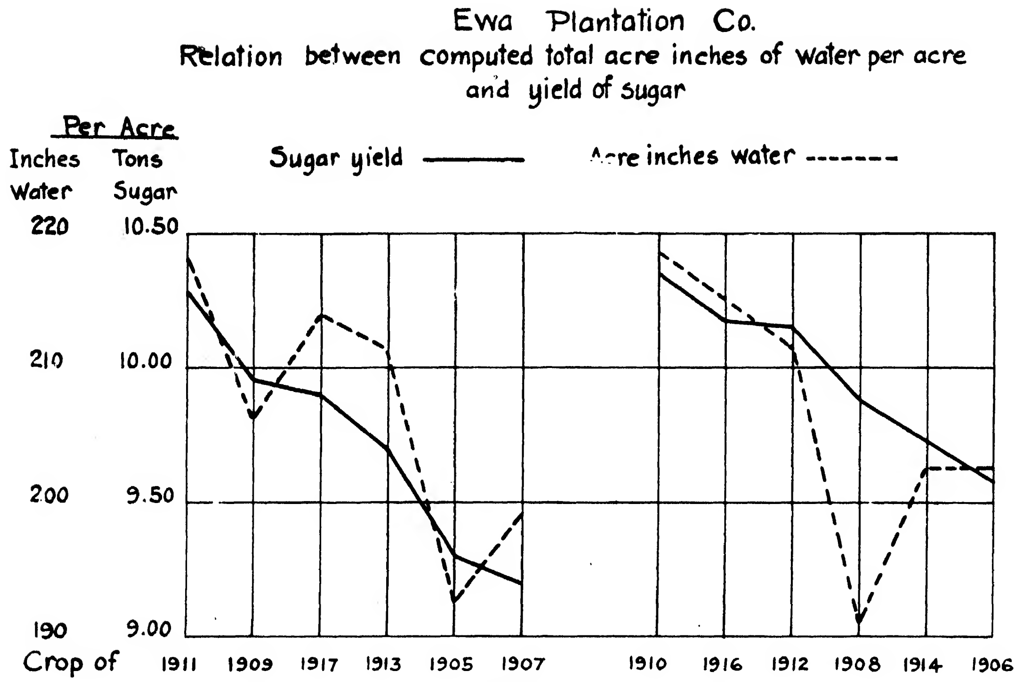


Fig. 6

The results are extremely interesting, for they show that there is a very good agreement between the total amount of water applied and the yield per acre. It is also significant that the average total water per crop for the group of odd years is practically the same as for the group of even years; also the deviations in percentage of the average of the individual years is of the same nature as the percentage deviation of the sugar yields.

This average of 207 inches of water per crop is not materially different from the figure obtained by Renton(14). We also see that this 207 acre inches produce on the average 9.85 tons of sugar in the selected group of Lahaina fields. Therefore, one ton of sugar requires approximately 21 inches or 570,000 gallons of water. These figures represent what is termed, gross duty of water, that is water measured at the source.

The Distribution of Water at Ewa

Having found that there existed a definite relation between total water and the yield of sugar, the next step was to determine whether it was the amount of water over the whole crop period or the amount in any particular season that was of more importance. This required a detailed story of the distribution of irrigation water and rainfall from month to month and from year to year. At Ewa over the period 1903-1917, there were no field measurements of irrigation water. The monthly distribution of water had, therefore, to be obtained in another manner. From individual pump records we calculated the total amount of irrigation water pumped each month. Then, for the same month we obtained the area under irrigation by consulting the dates of starting and harvesting of all the fields in cultivation. For this purpose all fields were assumed to come under irrigation

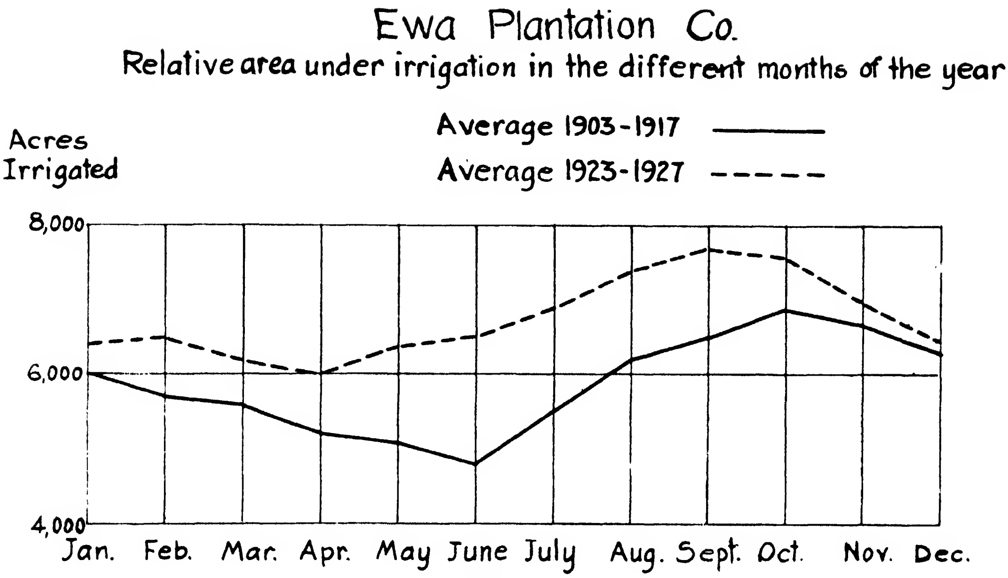


Fig. 7

as soon as started and to have an uniform non-irrigation interval of two months before harvest. (The interval was not, however, so long in some of the earlier years). Fields started or harvested before the 15th of the month we regarded as having been started or harvested on the first of the same month and if after the 15th of the month we calculated them from the first of the next month. The total amount of irrigation water pumped each month and the total area under irrigation are given in Appendices C and D. This latter information is presented graphically in Fig. 7. We see from this figure that as a rule the month of June has the smallest area under irrigation.

Dividing, then, the total water by the total area we get the amount of water per acre for each month. The data are presented in acre inches per acre which means that were the total water spread evenly over the area under irrigation, each acre would be covered to a depth of so many acre inches. The distribution of irrigation water is shown in Appendix E.

Irrigation Value of Rainfall

To the amount of water received from irrigation must be added the amount derived from rainfall· Evidently not all the rain water reaches the ground. How much of it does in a field of growing cane? At Ewa the highest average monthly rainfall is only 3.74 inches. Also, most of the rain comes in small irregular showers and is surely lost by direct evaporation from the leaves before it reaches the ground.

J. F. Voorhees, of the local Weather Bureau, assures us that we could safely disregard the showers that were less than 0.25 inch. In cane fields showers of 0.5 inch or even more could be neglected as having no irrigation value. Taking, however, 0.25 inch as the limit we went through the hourly precipitation data for Honolulu to determine how much of the total rainfall could be neglected as hav-

ing never reached the ground. This was found on the average to be about half the total rainfall.* Then, from the weather records of Ewa, we singled out only those months as having some irrigation value which had a precipitation of at least 0.50 inch during any 24-hour period. Half the total rainfall for these months only were then added to the amount of irrigation water for the respective months. Thus finally we obtained fairly reliable information as to the monthly distribution of water from 1903-1917. In the absence of exact data, those thus obtained are regarded as being accurate enough for strictly comparative purposes. The data are presented in Table IX and the monthly averages together with mean monthly temperatures in Fig. 6. We see from this figure that generally the month of June has the largest amount of water, while the highest temperature comes in the month of August, thereby suggesting a probable shortage of water in July and August.

TABLE IX

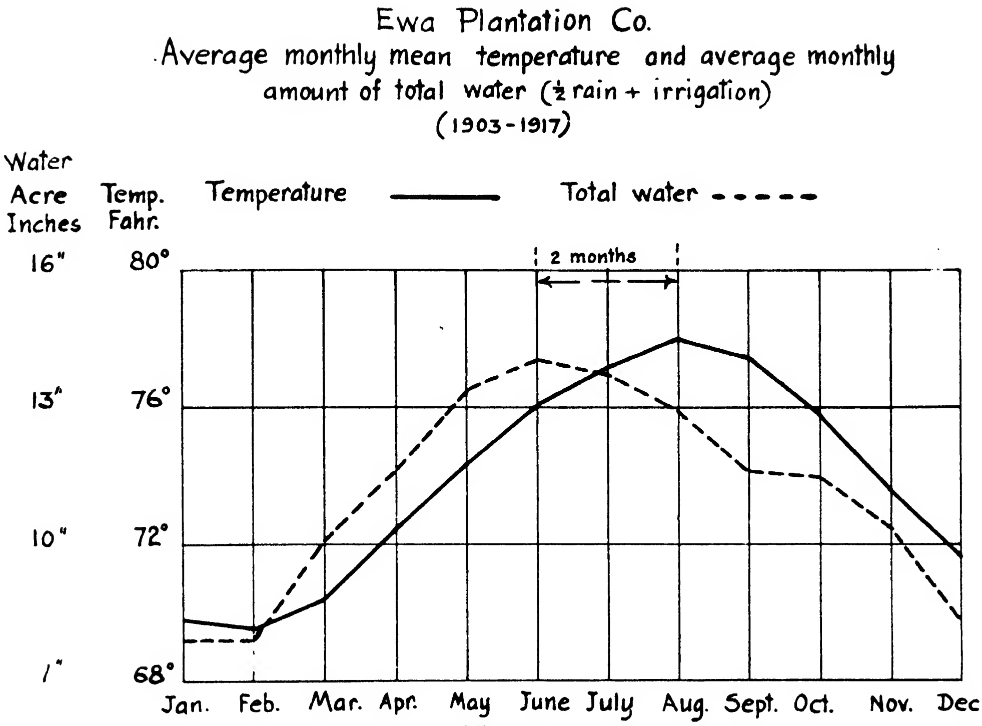
DISTRIBUTION OF WATER

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1903	6.95	6.38	9.99	10.53	11.51	12.26	12.02	12.91	12.18	10.88	7.89	7.46
1904	7.85	13.59	3.40	4.22	11.08	11.21	11.82	12.50	11.21	11.42	10.61	6.58
1905	8.72	8.18	9.44	10.55	12.96	12.42	11.58	11.73	10.25	10.50	10.65	7.04
1906	6.25	8.47	11.65	12.34	12.65	11.64	10.46	10.16	9.93	9.89	11.53	5.59
1907	6.89	2.15	7.29	12.40	14.09	11.78	12.05	11.32	9.98	9.88	8.97	10.13
1908	9.83	9.57	9.48	10.53	15.23	14.59	14.93	14.28	13.02	10.94	10.37	10.41
1909	9.16	9.07	11.23	13.52	11.32	17.27	17.07	14.69	11.66	12.10	11.65	10.24
1910	5.75	13.56	10.96	13.56	14.57	12.67	11.54	12.33	7.83	11.80	9.08	11.95
1911	2.28	7.01	8.08	11.88	15.66	17.15	17.94	14.10	13.75	11.94	12.91	11.34
1912	11.91	5.75	12.83	12.76	17.90	16.13	13.44	12.78	11.58	11.73	10.19	7.67
1913	10.90	8.12	13.58	14.07	10.59	10.40	13.10	11.95	11.79	12.15	11.91	7.34
1914	6.97	8.15	10.65	8.86	12.50	15.39	14.31	13.63	11.87	12.16	11.71	5.15
1915	11.06	10.10	13.95	13.44	12.55	15.60	14.78	13.44	12.66	12.36	6.57	9.45
1916	8.30	3.89	9.47	13.85	15.03	15.27	15.31	16.19	13.57	12.59	11.41	8.95
1917	4.92	4.26	9.92	11.72	14.70	15.46	14.54	13.75	12.00	11.71	11.08	5.41
1918												
1919												
1920												
1921												
1922												
1923	3.43	3.98	8.43	8.31	12.62	14.48	13.86	12.98	12.38	12.98	11.14	12.04
1924	4.19	9.26	12.12	7.59	10.78	13.80	15.58	14.66	12.68	12.73	10.28	6.48
1925	5.99	11.04	12.09	12.53	14.03	14.90	13.28	12.05	12.29	12.25	8.20	7.14
1926	9.47	9.95	13.49	10.75	12.46	10.15	13.67	13.08	12.46	11.67	8.39	9.12
1927				7.76	12.46	13.39	13.04	13.72	13.12	12.81	10.60	12.91
1928												
Average 1903-1917	7.85	7.90	10.13	11.60	13.49	13.95	13.66	13.05	11.55	11.47	10.44	8.38

High-Yield and Low-Yield Years

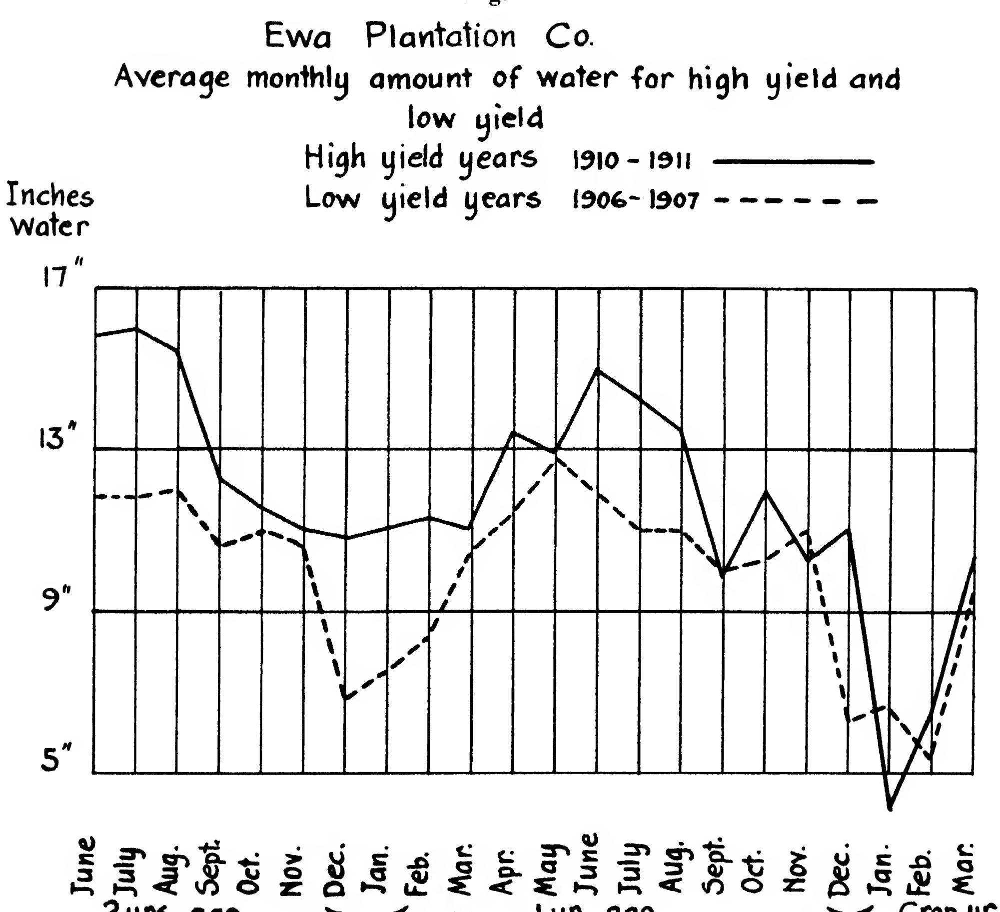
Now we can proceed with the comparison between the high-yield years, 1910 and 1911, and the low-yield years, 1906 and 1907, in the matters of seasonal distri-

* H. A. Wadsworth, associate professor of irrigation investigations, University of California, tells us that in their investigations it is customary to take only half the amount of rainfall as having irrigation value.



Ewa Plantation Co.
Average monthly mean temperature and average monthly amount of total water (½ rain + irrigation)
(1903-1917)
Water Acre Inches
Temp. Fahr.
Temperature
Total water
2 months
16"
80°
13"
76°
10"
72°
1"
68°
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.

Fig. 8



Ewa Plantation Co.
Average monthly amount of water for high yield and low yield
High yield years 1910 - 1911
Low yield years 1906- 1907
Inches Water
17"
13"
9"
5"
June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar.
2 yrs. ago
1 yr. ago
Crop yr.

Fig. 9

bution of moisture and warmth. We start from the month of June because in 1903-1917, the fields were usually cut back and the crop started in that month. Table X and Fig. 9 show the average amount of water in each month for the high-yield and low-yield years.

TABLE X

MOISTURE AND WARMTH IN THE HIGH-YIELD AND LOW-YIELD YEARS

High-yield years—1910, 1911
Low-yield years—1906, 1907

		High-yield years Acre inches water	High-yield years Average Temp. ° Fahr.	Low-yield years Acre inches water	Low-yield years Average Temp. ° Fahr.
2 years ago	(June	15.93	84.7	11.81	82.2
	(July	16.00	85.2	11.80	83.4
	(August	14.48	86.0	12.11	83.7
	(Sept.	12.34	85.8	10.73	83.5
	(Oct.	11.52	84.4	10.96	80.8
	(Nov.	11.01	83.0	10.63	78.5
	(Dec.	10.82	79.6	6.81	76.5
1 year ago	(Jan.	7.45	77.9	7.48	73.9
	(Feb.	11.31	78.6	8.32	75.7
	(March	11.09	79.0	10.54	75.9
	(April	13.44	80.5	11.44	80.2
	(May	12.94	82.9	12.80	82.0
	(June	14.97	84.6	12.03	83.6
	(July	14.30	85.5	11.02	84.4
	(Aug.	13.51	86.1	10.94	84.6
	(Sept.	9.71	85.9	10.09	84.5
	(Oct.	11.95	84.4	10.19	83.1
	(Nov.	10.36	82.7	11.09	81.3
	(Dec.	11.09	79.7	6.31	77.9
Crop year	(Jan.	4.01	77.7	6.57	77.2
	(Feb.	6.38	78.3	5.31	78.0
	(March	10.45	80.2	9.47	72.1

It is seen from Fig. 9 that the significant differences in the supply of water occurred in the first and second season summer and in the first and second season December. We can readily believe that a generous supply of water in the summer months will favor increased production and, therefore, the distribution of water was more ideal for the high-yielding years. The importance of a larger supply of water in December is not, however, so easily understood. We shall discuss this interesting point more fully in the course of our correlation studies.

Table X and Fig. 10 give the average monthly temperature for the high-yield and low-yield years. For reasons which we shall show later, here we have preferred monthly mean maximum temperatures.

It will be noted in Fig. 10 that the good years had uniformly higher temperature than the poor years and also that the greatest differences obtained in the fall and winter months of the first season. This is quite in agreement with the results reported in our previous paper(2) that at Pepeekeo the good years had uniformly more warmth than the poor years and that high temperatures in the early life of

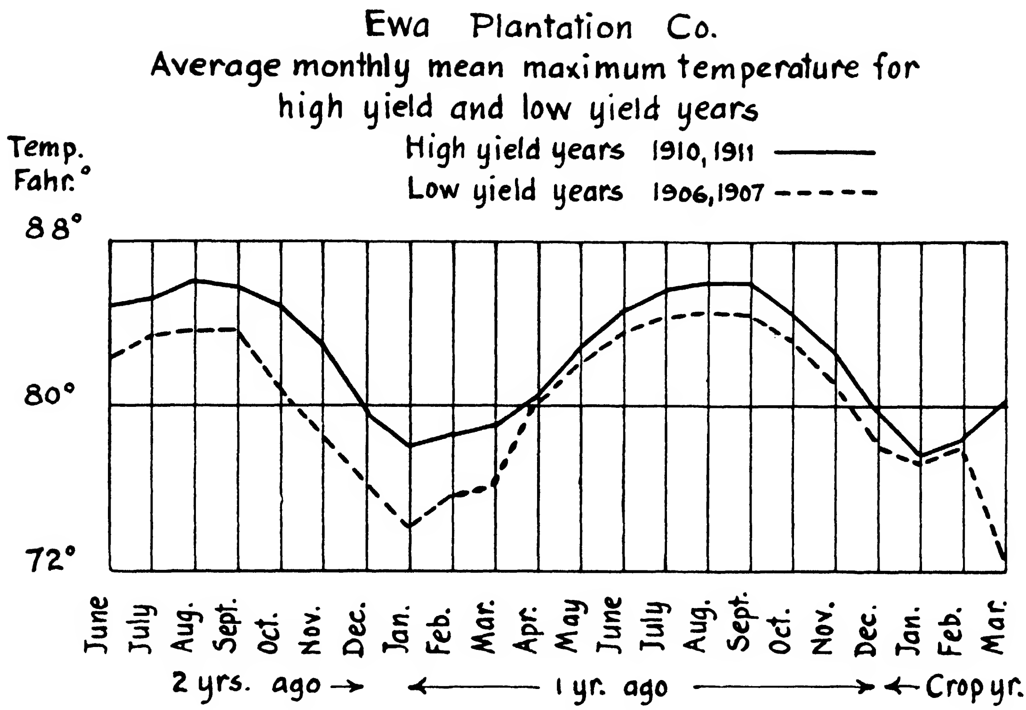


Fig. 10

the crop were of more significance than at any later period. We may say that in the years 1910 and 1911 the conditions of warmth were such as to favor high production.

Correlation Studies

To understand more precisely the relative significance of the different months or the different seasons in the matter of sugar production, we have employed the biometrical methods of correlation. If two variables, such as yield of sugar and available water, show linear relationship, then it is possible to express the correlation by, what are termed, the "correlation coefficients." The coefficients can be + or —, depending on whether the two variables vary simultaneously in the same direction or in the opposite. They can have any value from 0 to $\pm$ 1; 0 when there exists no relation whatsoever between the variables, and $\pm$ 1 when there is perfect correlation. It is also customary to attach a "probable error" to each coefficient to briefly indicate the reliability of the coefficients. This probable error is derived from the equation $E_r = .674 \frac{(1-r^2)}{\sqrt{n}}$ where r = correlation coefficient and n the number of items. Fisher(3) has recently shown that in agricultural studies where the number of items is usually limited, the use of probable error is unsatisfactory as it highly exaggerates the significance of the coefficient. In these studies we have used what Fisher terms probability index for different levels of significance. In our case the number of items being 13, the coefficient must be

more than .56 to be of definite significance; coefficients less than .56 may not be paid serious attention. An illustration of the manner in which the coefficients were obtained is given in Appendix F.

Water and Sugar Yield

Table XI and Fig. 11 give the coefficients of correlation between the supply of water in each month and the yield of sugar. First we see in Fig. 11 that the coefficients have usually high positive values in the summer months and low positive and at times low negative values in the winter. In other words, this trend of values indicates that in the summer months the supply of water should be more generous; that in the winter months the normal supply is ample. We also see that the months of June, July, August, October and December of the previous

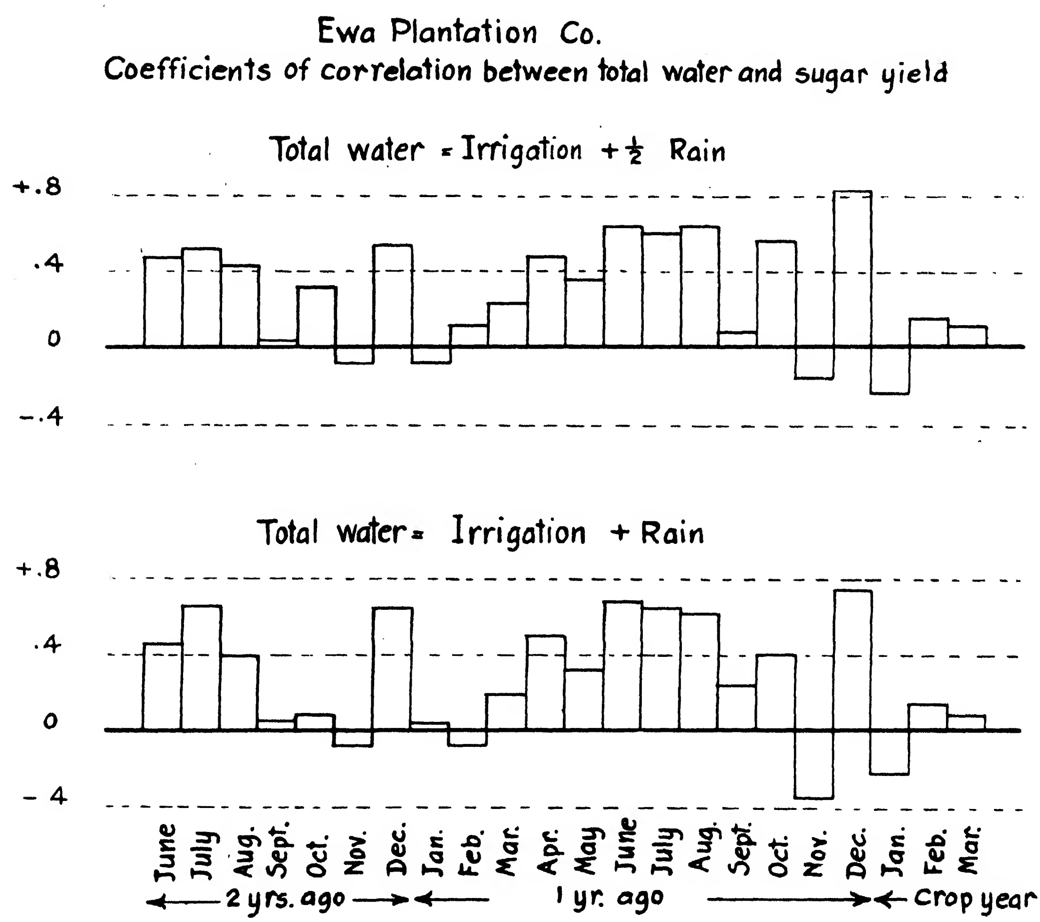


Fig. 11

year (for the crop of 1905 this will be the year 1904) have positive coefficients of definite significance, i.e., more than .56. This would indicate the critical importance of a large supply of water in those months in the big cane. We will readily grant that in the months of June, July, August and October, when high temperature favors rapid growth, the second season cane will require plenty of water; and also that any shortage at this period will materially decrease the yield.

But what about the importance of water in December? Elsewhere we have suggested that the normal supply of water in December, specifically in the years 1903-1917, may not have been ample. From Fig. 8 we see that the average supply of water in December is only 8.38 inches, or just about the same as in January and February. But the temperature in December is higher than in either of these two months, in fact, it is higher than in March; therefore, under normal conditions the growth of cane should be very much greater in December than either in January or February. Then, the demand for water should also be greater in December; in order words, if the supply in January or February is ample, then there are reasons to believe that the same supply in December is below the optimum. As a result of careful experiments, Renton and Alexander(14) found 5-6 inches of water in December to be the optimum for first season cane at Ewa, this water being measured right in the field. Adding to these figures the loss in transit of about 40 per cent due to evaporation, seepage, etc., we find the gross amount to be 8.3-10 inches. Therefore, it is reasonable to think that for second season cane the normal gross of 8.38 inches may be below the optimum. From a study of the detailed records in Table IX it is seen that it was in the month of December that the most unequal distribution of water has taken place from year to year. That is, while some years had water considerably above the normal, others had considerably below it. We also discovered from a study of rainfall records that the years when this deficiency occurred were the years when there was a fair rainfall in the month in question, and as a result very little irrigation. Our study suggests that the value of rainfall, particularly in December, had been overemphasized and the demand of the cane underestimated. Now, it may be asked what results we would have obtained if we had allowed rainfall to have full value instead of half as we did. Anticipating such a question, we have worked out the

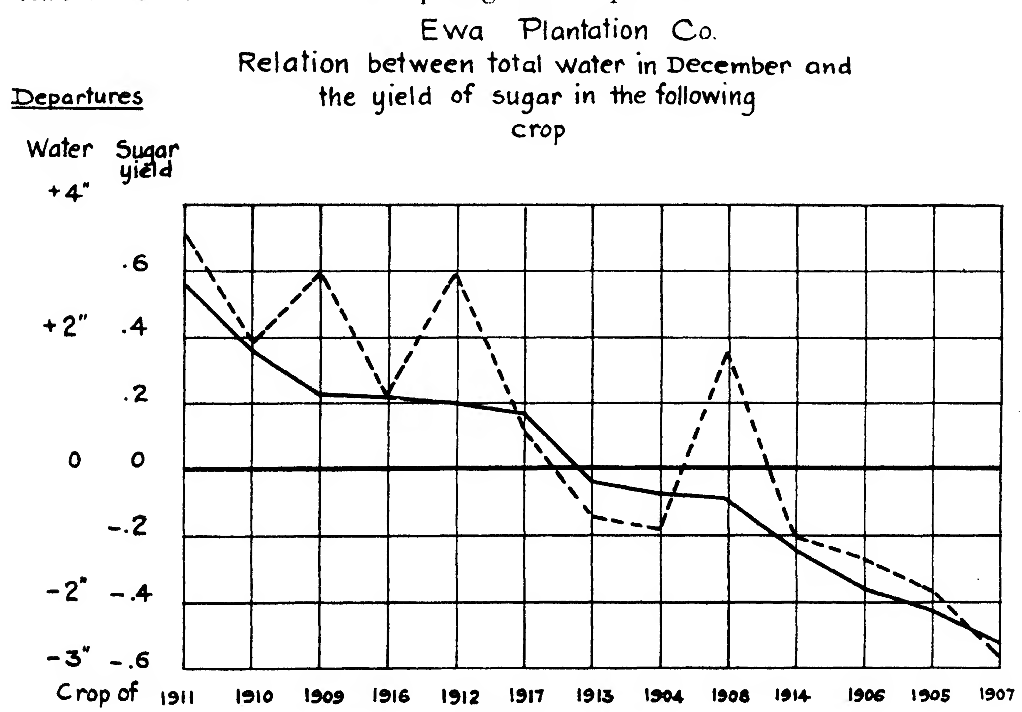


Fig. 12

correlative coefficients for the different months adding the full value of rainfall to irrigation water. The coefficients are shown in Fig. 11. The significant periods retain their significance and the month of December of the previous year still has the highest coefficient. This relation between the supply of water in the December of the previous year and the yield of sugar is shown graphically in Fig. 12.

The lack of significance of the coefficient for September of the previous year is not quite understood. However, the coefficient for the combined supply of water in June to October, inclusive, and sugar yield is found to be .58, that is the entire second season summer requires more than normal supply in order to produce yields above the average.

Temperature and Sugar Yield

In a place like Ewa where under natural conditions there is more warmth than water to go with it, the study of the relation of temperature to sugar yield is necessarily complicated. For even when high temperature shows harmful effects, it may do so not because temperature is harmful *per se* but because at high temperatures there is not a correspondingly large supply of moisture. From a knowledge of the seasonal supply of water at Ewa, we would expect that for optimum conditions we should have moderately cool summers and fairly warm winters.

TABLE XI

CORRELATION COEFFICIENTS

		Sugar yield and water	Sugar yield and mean monthly t°	Sugar yield and maximum monthly t°	Sugar yield and minimum monthly t°	Sugar yield and monthly range of t°
2 years ago	(June	.48	.54	.53	.43	.36
	(July	.52	.41	.46	—.18	.48
	(Aug.	.45	.11	.39	—.27	.54
	(Sept.	.05	.18	.45	—.23	.56
	(Oct.	.31	.32	.58	—.28	.81
	(Nov.	—.07	.42	.64	—.21	.66
	(Dec.	.54	.14	.38	—.16	.17
1 year ago	(Jan.	—.08	.19	.34	.09	—.29
	(Feb.	.12	.47	.55	.27	.04
	(Mar.	.24	.63	.60	.47	—.12
	(April	.47	—.01	.34	—.21	.47
	(May	.36	.33	.22	.31	.03
	(June	.63	.14	.18	.06	.19
	(July	.59	—.02	.14	—.17	.24
	(Aug.	.63	—.16	.00	—.44	.53
	(Sept.	.09	—.15	.07	—.42	.36
	(Oct.	.56	—.08	.15	—.48	.54
	(Nov.	—.16	.19	.31	—.09	.38
	(Dec.	.82	.04	.18	—.13	.17
Crop year	(Jan.	—.23	.18	.15	.19	—.39
	(Feb.	.15	.28	.17	.32	—.28
	(March	.13	.45	.44	.39	—.14

Table XI and Fig. 13 give the coefficients of correlation between monthly mean temperature and sugar yield. We see from this figure that the coefficients

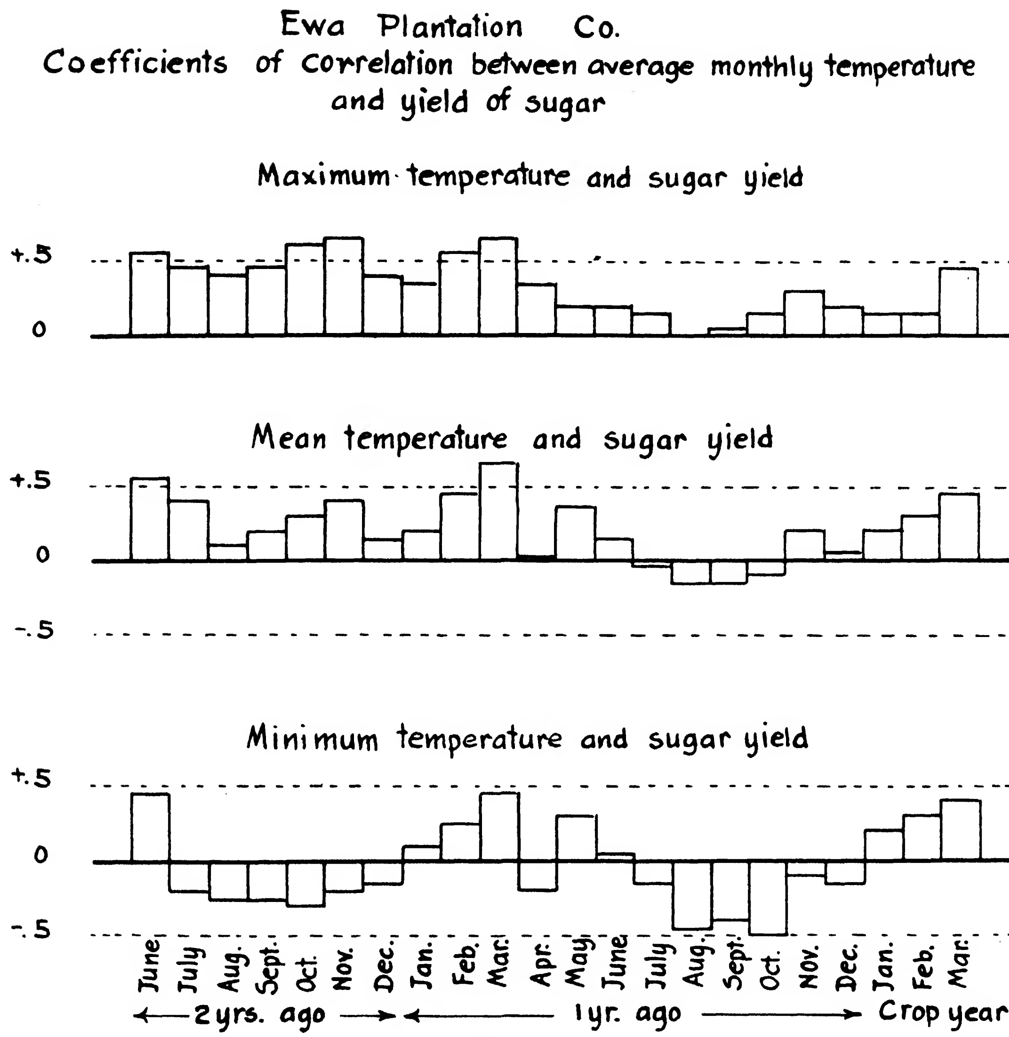


Fig. 13

are generally higher in the first season or two years ago than in the second season or the previous year. Also, all the coefficients are positive except in the months of July to October of the previous year; and the winter month of March of the previous year has the only significant value. The results in general, but not as conclusively, support our findings in the case of Pepeekeo(2). These are, however, just as we had already anticipated from theoretical considerations of the local conditions.

Maximum Temperature and Sugar Yield

Koenig(5) in Mauritius found that monthly mean maximum temperature showed a more definite relation to sugar yield than the monthly mean temperature. In order to determine if such was the case, we next obtained the coefficients of correlation between the monthly mean maximum temperature and sugar yield; the coefficients are given in Table XI and Fig. 13 (the detailed records of maximum temperature are given in Appendix G).

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	(Mar.	.24	.63	.60	.47	—.12
	(April	.47	—.01	.34	—.21	.47
	(May	.36	.33	.22	.31	.03
	(June	.63	.14	.18	.06	.19
	(July	.59	—.02	.14	—.17	.24
	(Aug.	.63	—.16	.00	—.44	.53
	(Sept.	.09	—.15	.07	—.42	.36
	(Oct.	.56	—.08	.15	—.48	.54
	(Nov.	—.16	.19	.31	—.09	.38
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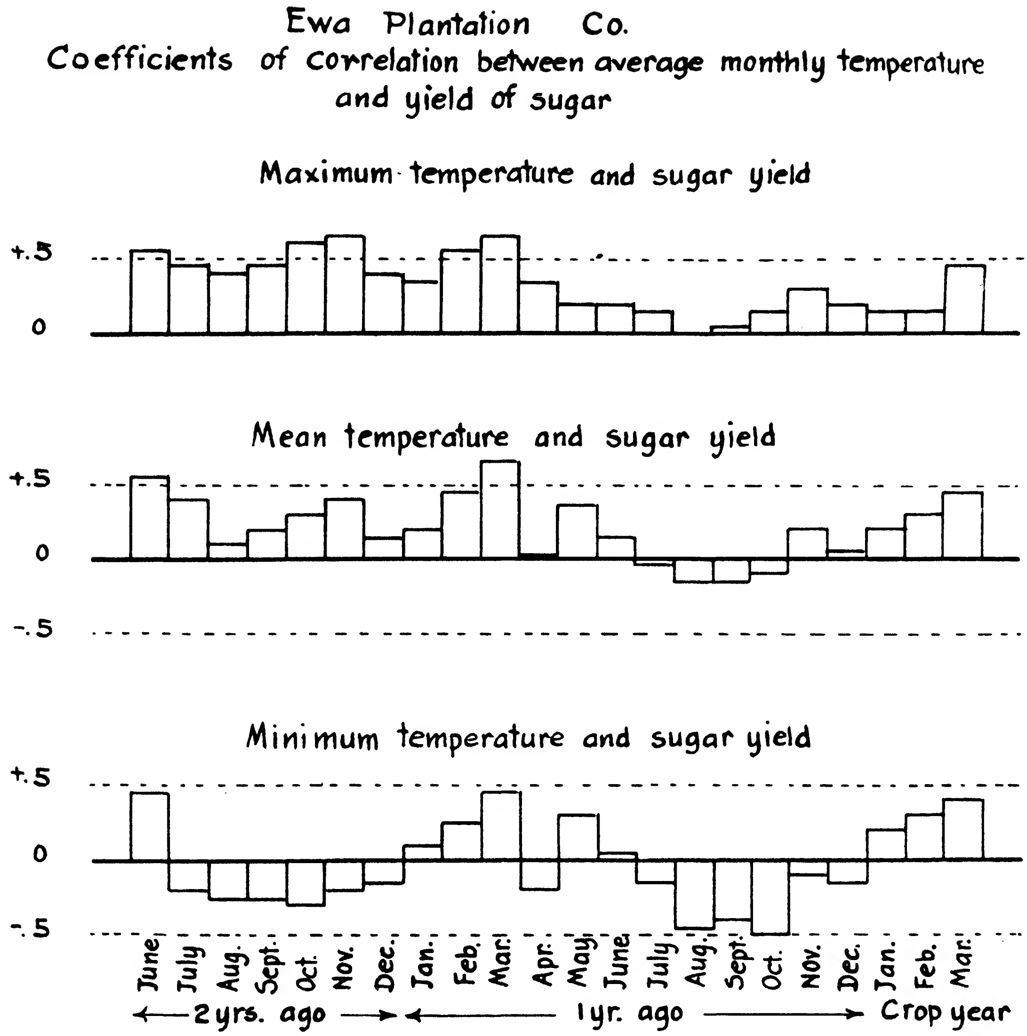

Fig. 13

are generally higher in the first season or two years ago than in the second season or the previous year. Also, all the coefficients are positive except in the months of July to October of the previous year; and the winter month of March of the previous year has the only significant value. The results in general, but not as conclusively, support our findings in the case of Pepeekeo(2). These are, however, just as we had already anticipated from theoretical considerations of the local conditions.

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We consider the results very satisfactory, for they conform better with the existing knowledge of the relation of temperature to cane growth and sugar yield. We observe that the coefficients are generally high in the first season and low in the second and that all of them are positive. This means temperature of itself does not do any harm, though the very small values in the summer months of the second season can only be explained as indicative of a probable shortage of moisture in that period. The months of October and November, two years ago, and the month of March one year ago have significant coefficients. Assuming the average date of starting to be the month of June, we see that these significant months fall within the first year in the life of the crop. This again points out the importance of warm growing conditions in the early life of the plant as being essential to high production. As has been shown by Verret and Das(18) the rate of growth of a cane plant is at the maximum between the ages of 5 to 12 months. Is it not then reasonable to think that a cane plant will get the maximum benefit out of a favorable growing condition when biological forces cause it to develop the most rapidly? It is also gratifying to see that these present results agree so well with our previous findings at Pepeekeo. After all, Pepeekeo and Ewa are in the same climatic zone and the results from one should generally apply to the other.

Minimum Temperature and Sugar Yield

Now we come to the interesting relation of monthly mean minimum temperature to sugar yield. Having determined the effects of monthly mean and monthly maximum temperatures on sugar yield, it was but natural that we would have wanted to find the effects of monthly mean minimum temperature. Table XI and Fig. 13 give the coefficients of correlation between minimum temperature and sugar yield. (The records of minimum temperature are given in Appendix H).

These results appear rather confusing at first but prove to be very suggestive upon close examination. We see from Fig. 13 that the coefficients are as a rule negative except in the winter months. There is not one significant value, but the persistence of the negative correlation from month to month proves beyond doubt the existence of a negative correlation, between minimum temperature and sugar yield. In other words, in the months of July to December two years ago, and the months of April to December of the previous year, minimum temperature above the normal is likely to bring the yield of sugar below the average. This naturally leads us to the necessity of clearly defining the roles played by maximum temperature and minimum temperature in the growth of the cane. We will not discuss mean temperature for, after all, it is an unreal quantity—merely a conventional term. This mean temperature, as we know, is obtained by dividing by two the sum of the maximum and the minimum temperature. Therefore what actually affects the cane is the maximum and the minimum temperature; mean temperature does so only in the sense that it is partly derived from the other two temperatures.

Under the influence of sunlight the leaves of the sugar cane plant take the carbon dioxide out of the air and with the help of moisture, maybe other substances, brought up by the roots, they build up carbohydrates. This process goes on only under the influence of light and ceases altogether at night. So we may say that the actual growth, not elongation of the stalk, takes place only by day.

Now, maximum temperature is an index of day temperature just as minimum temperature is of the night. High maximum temperature means high day temperature which again is indicative of brighter sunlight or more sunlight. More sunlight means more total assimilation of carbon dioxide. Brighter sunlight means greater plant activity because the temperature of the plant is considerably raised by direct sunshine. And as a result, as Seely(16) has shown, there is more plant growth. So we see high maximum temperature is only an index of favorable growing conditions by day.

What then is the role of minimum or night temperature? We know the carbohydrates are made in the leaves by day and they are sent to other parts of the plant at night. Could it be possible that high minimum temperature stands in the way of such translocation of materials? There is to our knowledge no definite information on the point.

But the fact that for the same months high maximum temperatures are found to be beneficial and high minimum harmful, suggests that for ideal conditions we must have high maximum or day temperature and low minimum or night temperature. This amounts to the same thing as saying that for optimum conditions we must have a wider range of temperature. The next thing then was to find the relation between range of temperature and sugar yield.

Range of Temperature and Sugar Yield

Table XII is a record of monthly range of temperature at Ewa. The data have been obtained by calculating the difference between the monthly mean maximum and the monthly mean minimum temperatures. Table XI and Fig. 14 gives the correlation coefficients.

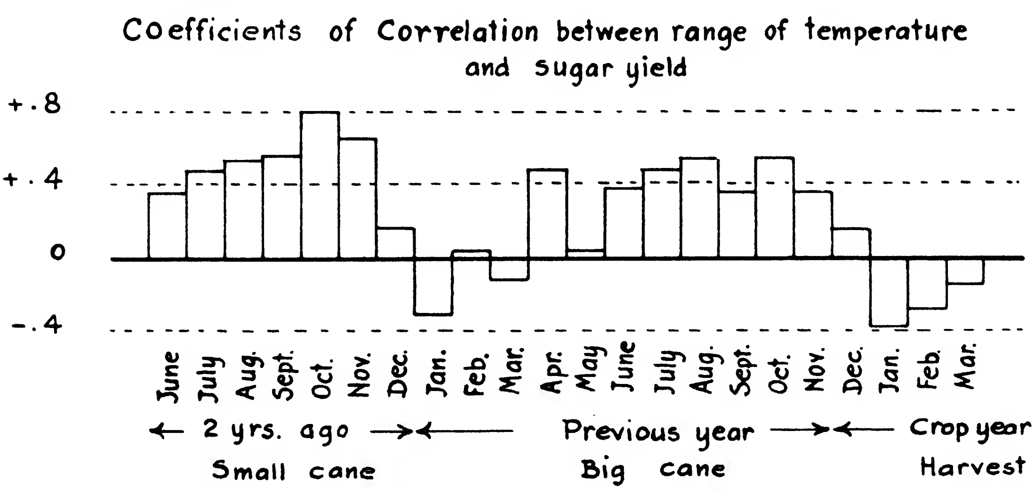

Fig. 14

The coefficients show unmistakably the existence of a high degree of correlation between range of temperature and sugar yield at Ewa. We find they are generally positive except in the winter months and that the significant values obtain in September to November two years ago, that is, when the cane was from 4 to 6 months old. How can we explain the evident importance of the range of temperature to increased production?

Range of temperature may increase the yield of sugar—(a) directly, in the sense that it is of biological importance to the sugar cane plant in the matter of its health and reproduction; (b) indirectly, in the sense that it is only associated with other conditions which promote growth.

The effect of a range of temperature or rather of alternating temperature on germination of seeds has long been recognized. Harrington(4) has shown the excellent effects of alternating high and low temperature on the germination of seeds of many species of plants. He has found that for every variety there is a certain range of temperature in which there is not only a greater percentage of and quicker germination of seeds, but also more vigorous seedlings. The exact reasons are not yet well understood but it is believed that the range of temperature has something to do with the metabolic activity of the dormant seed. More recently Morinaga(12) has found that not only the range of temperature is helpful to germination but in some species of plants its good effects are augmented in the presence of nitrogen and light. May it not be that in the case of sugar cane a wide range of temperature quickens the germination of buds and increases the production of healthy, vigorous shoots?

TABLE XII

AVERAGE MONTHLY RANGE OF t° (DIFFERENCE, MAXIMUM AND MINIMUM)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1903	17.0	16.0	20.0	16.0	17.2	18.0	15.0	15.8	16.1	15.0	16.2	16.5
1904	15.0	13.0	12.6	12.8	17.8	16.2	16.9	16.3	17.0	13.9	14.0	13.3
1905	17.6	18.1	17.5	15.1	14.1	15.2	13.6	12.0	12.7	13.1	13.2	13.9
1906	19.1	20.1	19.6	16.2	19.8	16.7	16.7	15.7	17.8	16.3	17.1	16.7
1907	15.6	17.8	15.6	19.3	19.3	18.1	17.6	15.0	16.9	17.4	16.2	17.6
1908	18.2	18.3	15.7	17.2	17.6	18.1	18.1	18.1	18.5	18.4	20.0	16.1
1909	18.1	17.1	13.4	17.6	17.9	16.6	15.9	17.3	18.7	17.7	19.5	16.6
1910	15.4	18.7	17.9	16.5	18.0	16.7	18.4	18.2	18.2	17.6	16.1	17.4
1911	14.2	16.3	17.1	17.0	17.5	16.4	15.9	17.0	15.8	18.0	17.1	15.5
1912	17.7	17.3	17.9	17.4	18.5	18.2	18.1	18.2	18.2	17.0	17.1	15.0
1913	18.2	19.4	18.8	17.5	17.9	17.7	19.2	18.7	18.7	18.7	16.2	19.3
1914	17.3	20.8	18.2	18.4	17.8	18.1	16.4	16.7	15.0	18.1	16.4	17.1
1915	17.2	16.3	18.9	18.6	18.9	18.5	17.6	17.4	18.2	16.7	14.3	14.3
1916	15.1	18.1	15.9	17.0	15.7	16.0	16.6	17.0	16.7	16.1	14.8	15.4
1917	17.8	18.1	15.5	17.2	19.0	18.2	18.9	18.5	19.4	19.4	17.4	17.4
1918												
1919												
1920												
1921												
1922	18.2	17.3	19.2	19.4	20.0	21.0	21.6	20.4	20.5	20.3	20.4	23.0
1923	16.4	22.8	19.9	20.7	21.9	22.9	21.0	22.0	21.6	22.8	20.8	18.8
1924	24.5	22.6	22.6	20.7	22.0	23.0	21.7	21.9	23.1	21.3	21.5	22.2
1925	19.4	20.7	22.3	19.5	21.2	20.7	21.1	21.0	22.6	23.5	20.8	19.2
1926	19.8	19.8	20.8	19.8	18.5	18.6	19.5	19.3	19.0	18.7	20.4	17.7
1927	17.8	20.1	16.6	18.5	18.1	18.7	17.4	18.9	19.9	19.4	16.0	16.9
1928												
Average 1903-1917	16.9	17.7	17.0	16.9	17.8	17.2	17.0	16.7	17.2	16.9	16.4	16.1

We note that the range of temperature is most effective when the cane is 4 to 6 months old, that is, when it has just started to form stalks and send out new shoots. As has recently been shown by Rodrigues(15) in Louisiana, early suckering means more uniformly mature stalks at harvest and consequently more sucrose in the crop.

So far we have considered only the phase of reproduction and multiplication in the cane plant, but it may also be that a wider range helps to maintain the vitality of the plant itself—improve its tone, so to speak. It is also possible that a wide range of temperature at Ewa increases the beneficial activity of the vast soil population.

Range of temperature may be only an associated cause, for a high range of temperature generally indicates clearer and brighter days and consequently, as we have tried to show, there is more plant activity and more growth.

Not only are the months of September to November in the year of starting of the crop of significance, but the combined period of seven months from June to December has a significant coefficient of .76.

Partial and Multiple Correlations

We have found that at Ewa the good yields were associated with better distribution of water in the periods when the crop needed it most. We have seen that the conditions of warmth and, probably, light were also nearer ideal in the good years than in the poor years. Now the question will arise as to what, then, is the relative importance of moisture and warmth in the several significant periods as brought out by this study? In other words, precisely how much of the high yields are due to water and how much to temperature? To satisfactorily answer these questions we will have to work out the coefficients of correlation between two variables when all other variables are eliminated; in other words, we will have to find the partial correlation coefficients.

But even the partial correlation coefficients are not what we are principally interested in. What we would rather know is how much yield can be expected as a result of the combined effect of the several elements of weather. It is probable that not all of these will be favorable or unfavorable at the same time. Perhaps the good work of one element will be partially or wholly undone by the adverse effect of another, or vice versa. What we want to know, then, is the multiple correlation or the combined correlation of several factors with yield.

In view of the meagerness of our data it is doubtful if any definite results can be obtained from such detailed study. However, in our next paper, we shall attempt to work out some of the coefficients mentioned above.

The Recent Years 1924-1928

These years, as we have said, are regarded by common consent to be free from any disturbing influence. These, then, should present a satisfactory subject for our studies of the relation of weather conditions to sugar yield. These years have seen a succession of record crops and their high level of production has never been attained before—not even in the heyday of Lahaina. The causes of these

high yields are given variously as follows: (a) the establishment of H 109 as the standard variety; (b) better control of field and factory operations; (c) steady labor conditions, etc. Though the weather has not received any special mention yet we naturally ask ourselves if in the light of our findings there are any grounds for believing that the record productions were only possible with the help of ideal weather conditions. Indirectly this present inquiry furnishes a test for the validity of our deductions from the study of the yields of 1903-1917.

Let us then take the year 1925, which has the highest per acre production of sugar. Let us compare the distribution of water and temperature for this crop as

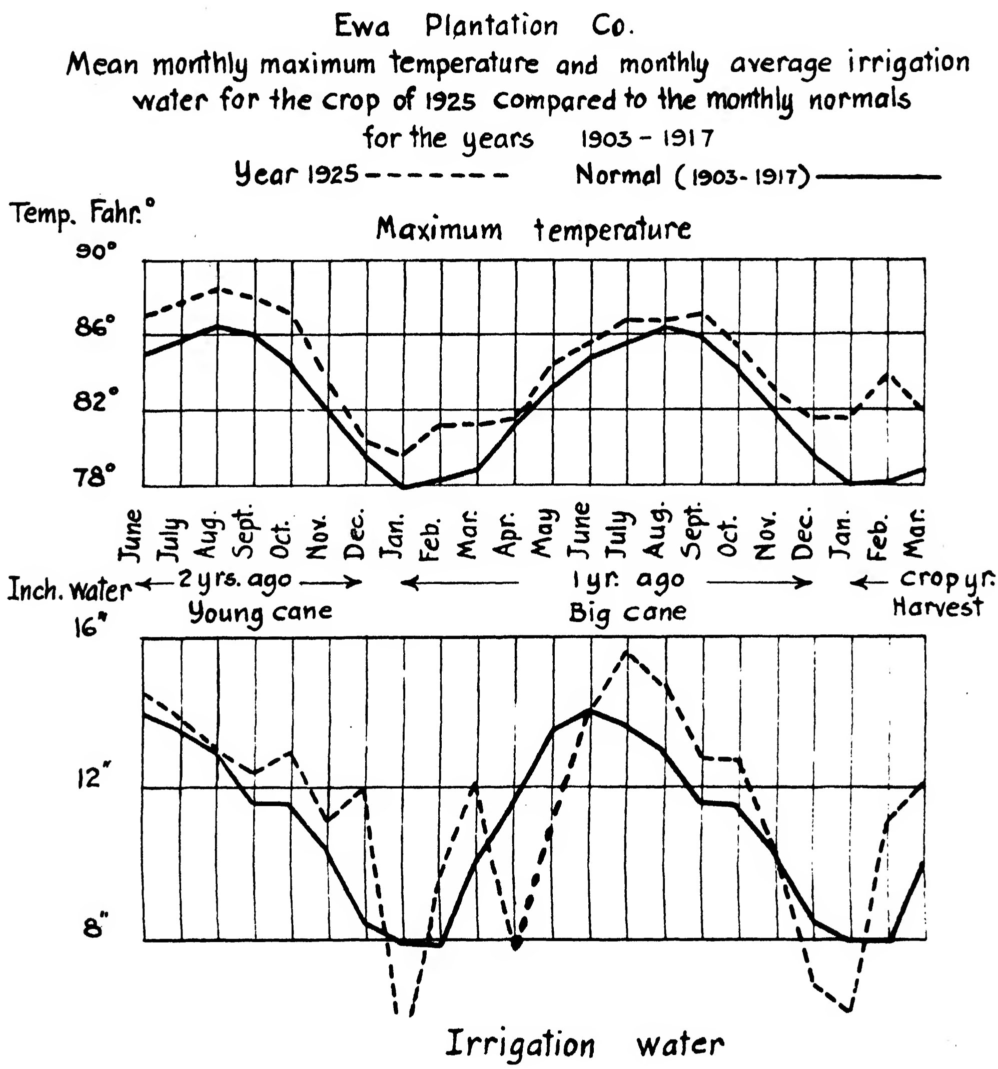

Fig. 15

compared to the normal. Fig. 15 shows the various data. We note that in the matter of water supply and more so in the matter of maximum temperature the year 1925 had been exceptionally favored. In fact, of all the recent years the crop of 1925 had the most ideal supply of water and the most ideal temperature conditions.

Let us now take all the years from 1925-1928 and compare them with the normal in the matter of total supply of water, seasonal supply of water, maximum temperature and range of temperature.

Total Water and Yield

Because of changed cultural practices the annual output of water in these years has been distributed as follows: two-fifths of the water in 1923 goes to the crop of 1925 and three-fifths to the crop of 1924 and so on. (These proportions were suggested by W. P. Alexander, head of the department of research at Ewa Plantation Company). Table XIII gives total water for four crops. The sugar yields are found in two columns—one of them gives the average yield for the whole plantation, including the yield from plant, long and short ratoons, the other gives the average yield from plant and long ratoons only from those fields which were included in the study of 1903-1917.

TABLE XIII

Crop year	Total water acre inches	Tons sugar per acre (all plantation)	Tons sugar per acre (selected fields only)
1925	210.85	11.87	14.12
1926	203.90	11.00	13.67
1927	213.36	11.24	13.24
1928	207.19	11.50	13.87
Average (4 years)	208.88	11.40	13.72

There is a general agreement between total water and the yield of sugar. But what is of more interest is that the average total water of 209 acre inches per crop is the same as the average for the years 1905-1917, which was found to be 207 inches per crop. But while formerly it required 21 acre inches of water to produce one ton of sugar, in the years 1925-1928, in the same group of fields, it required only a little over 15 acre inches for each ton.

Seasonal Supply of Water, Maximum Temperature, Etc.

Table XIV gives various information as to the distribution of water, temperature and range of temperature for the crops of 1925-1928 in the various periods that were found to be of definite importance.

TABLE XIV

Crop Year	Tons sugar p.a. (Selected *fields*)	Tons sugar p.a. (All plantation)	Total water June-Oct. *previous* year	Total water Dec. *previous year*	Average monthly maximum to June-*November* 2 years ago	Average monthly range of t°-June-*November* 2 years ago	Range of t° October 2 years ago
1925	14.12	11.87	69.45"	6.48	86.9°	21.9	22.8
1926	13.67	11.00	64.77	7.14	85.9	22.1	21.3
1927	13.24	11.24	61.04	9.12	85.5	21.6	23.5
1928	13.87	11.50	66.08	12.91	86.1	19.3	18.7
Average 1925-1928	13.72	11.40	65.34	8.91	86.1	21.2	21.6
Average 1904-1917	9.85		63.38	8.38	84.9	16.9	16.9

(Note—The differences in the averages for the two periods: 1903-1917 and 1925-1928 should be noted).

First of all, a study of the individual averages for the two periods, 1903-1917 and 1925-1928, shows that in every particular the recent years were better than the earlier years of 1903-1917. The greatest differences, however, were in the matter of temperature and range of temperature. Also a detailed study of each of the years 1925, 1926, 1927 and 1928, reveals that the variations in the yields of these years were definitely associated with the variations in the supply of moisture or warmth in the periods when either of these was needed most.

Computed Yields

From Table XIV we see that in the group of selected fields the average yield of sugar was 9.85 tons for the years 1904-1917; the average yield from the same fields was 13.72 tons of sugar in 1925-1928. This represents an increase of about 39 per cent. The question then naturally arises—"How much of this increase can be attributed to improved weather conditions or improved water supply?" In the absence of definite information as to the combined effects of the various factors such as the supply of water, the maximum temperature and the range of temperature at critical periods, it is impossible at present to fully answer this question. However, just to indicate the possibilities, we have here computed the sugar yields from one known weather condition, namely the range of temperature in October two years ago, which will be the October of 1923 for the crop of 1925. The regression equation has been derived from these known statistics—the mean and the standard deviation of the yields of 1904-1917, and the correlation coefficient of the weather element of the month in question. The equation can be represented thus:

$y = 7.18 + 0.158\,x$, where
y = yield of sugar in tons per acre
x = the range of temperature in October two years ago.

(For the theory and development of the regression equation, the reader is referred to some standard works on biometrics).

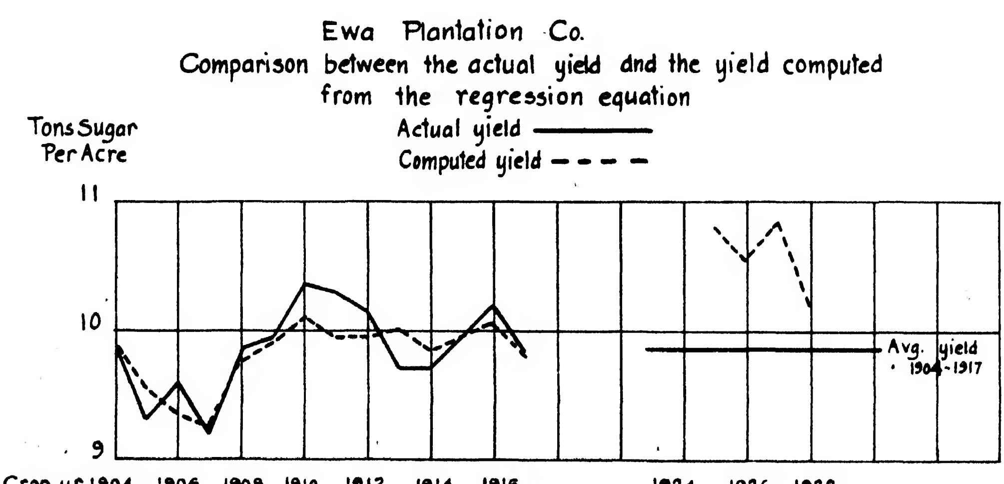

Fig. 16

Table XV and Fig. 16 give the yields computed from this equation. It should be observed that in deriving the equation, the yields of 1925-1928 were not considered; so what this equation actually does is to predict the sugar yields for these years from the known statistics.

TABLE XV

Crop year	Actual yield T.S.P.A.	Computed yield T.S.P.A.	Per cent deviation from actual	Crop year	Actual yield T.S.P.A.	Computed yield T.S.P.A.	Per cent deviation from actual
1904	9.89	9.91	0.2	1916	10.18	10.03	1.5
1905	9.30	9.55	2.7	1917	9.89	9.81	0.8
1906	9.58	9.37	2.2	Average	1904–1917		
1907	9.19	9.25	0.7		9.85	9.81	0.4
1908	9.87	9.85	1.2				
1909	9.95	9.92	0.3	1925	14.12	10.78	
1910	10.34	10.08	2.5	1926	13.67	10.54	
1911	10.29	9.97	3.1	1927	13.24	10.89	
1912	10.16	9.96	2.0	1928	13.87	10.13	
1913	9.69	10.02	3.4	Average	1925–1928		
1914	9.72	9.86	1.4		13.72	10.59	

We see from this table that the computed yields for 1904-1917, agree fairly well with the actual yield, the greatest deviation being only 3.4 per cent. We further note that the average computed yield of 1925-1928, which is 10.59 tons, is 7.5 per cent greater than the actual average of 1904-1917, which is 9.85 tons. The actual yield of 1925-1928, with a different variety of cane and under improved cultural conditions, is 13.72 tons; this yield is 39 per cent greater than the yield of 9.85 tons. In other words, 7.5 per cent of the actual increase could have been due to the favorable influences of this one element of the weather (or, perhaps, others associated with it) and the remaining 31.5 per cent, due to other causes. The combined effects of several weather elements would probably be greater than 7.5 per cent. If we look at it the other way, we might say that if in the coming years we are to have weather conditions similar to the average of 1904-1917 and if all other factors in sugar production remain the same, then our sugar yields may decrease by 7.5 per cent. This figure is merely suggestive and should not be taken at its face value.

Conclusion

It is possible that there will be criticisms of the manner in which we obtained the average yield of the plantation for the years 1904-1917. We do not think that these averages are exact but at the same time we believe that they are the most satisfactory ones that could be obtained. It may also be argued that the inclusion of the years 1905 and 1906 in our study was seriously in error. Granting for the sake of argument, that the supply of water or the weather conditions had nothing to do whatsoever with these low yields, we worked out the correlation coefficients eliminating these two years. Even then, we find that the several critical periods retain their significance.

Owing to the meagerness of our data, it is impossible to claim extreme accuracy for the results obtained herein. It was, however, believed that the data are sufficient enough to warrant the general soundness of our deductions.

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APPENDIX A

A CLASSIFICATION OF FIELDS ACCORDING TO SOIL TYPES (PREPARED BY THE EWA PLANTATION COMPANY)

Field No.	Area	Deep Ewa well drained	Deep Ewa palı	Deep Waipahu red	Poorly drained	Blue adobe Waimanalo	Coral
A	276.75	201.75		35.00	40.00		
B	167.16			167.16			
C	73.24	10.00			63.24		
D	11.36	11.36					
E	20.95				20.95		
1A	46.37	36.37			10.00		
B	17.52	17.52					
C	135.58	45.58	86.00				
D	46.86	36.86			10.00		
E	58.80	55.80			3.00		
F	125.18	125.18					
G	32.40	32.40					
2A	105.75	105.75					
B	21.28	21.28					
C	85.36	80.00			5.36		
3A	173.56				173.56		
B	150.55	140.55			10.00		
C	135.35				135.35		
D	99.02				99.02		
E	39.57	39.57					
4	152.00	102.00			50.00		
5	103.01	53.01			50.00		
6	120.10	120.10					
7	139.16	139.16				100.00	
8A	100.00	40.00			60.00		
B	82.45	60.00				22.45	
9A	111.27					111.27	
B	82.16					82.16	
10A	102.28				20.00		82.28
B	80.35		15.00		20.00		45.35
C	114.77						114.77
D	148.57						148.57
E	27.51						27.51
F	29.91				29.91		
11A	58.30				58.30		
12A	27.63				27.63		
B	99.70		99.70				
13A	52.38	25.00			27.38		
B	92.85				20.00		72.85
C	178.79						178.79
D	59.66						59.66
E	22.05	12.05					10.00
14A	53.14	10.00			43.14		
B	76.84	26.00			50.84		
C	106.10	56.10			10.00		40.00
15A	100.00	75.00	25.00				
B	126.06	126.06					
C	22.50				10.00		12.50

APPENDIX A—Continued

Field No.	Area	Deep Ewa well drained	Deep Ewa pali	Deep Waipahu red	Poorly drained	Blue adobe Waimanalo	Coral
D	61.20						61.20
16A	63.80	43.80		20.00			
B	49.55	49.55					
C	72.50	60.50					12.00
17A	77.86			77.86			
B	48.60	48.60					
C	4.15			4.15			
D	60.02				60.02		
E	29.11				29.11		
18A	25.40	15.40					10.00
B	54.00	27.00					27.00
19A	130.67	40.67		50.00		40.00	
B	67.80	67.80					
C	111.10	71.10			20.00		20.00
D	81.06			30.00	51.06		
E	24.04				24.04		
F	53.80	25.00					28.80
G	20.96						20.96
H	20.94			20.94			
I	51.06			51.06			
20A	53.48					53.48	
	14.63					14.63	
	24.69					24.69	
21A	112.80	30.00					82.80
B	82.75						82.75
C	49.00						49.00
22A	136.40						136.40
B	105.41	65.41					40.00
C	83.09						83.09
23A	82.70		82.70				
B	87.62	60.62		27.00			
C	59.08	44.08		15.00			
D	41.69					41.69	
24A	102.68		102.68				
B	50.81	50.81					
C	56.75	56.75					
D	70.00		70.00				
25A	125.88		25.88		90.00		10.00
B	183.04	33.04			10.00		140.00
C	57.97						57.97
D	51.11	46.11	5.00				
26A	89.14					89.14	
B	32.64					32.64	
C	69.10						69.10
D	35.95						35.95
27A	26.95		26.95				
B	31.82					31.82	
28A	139.96		139.96				
B	30.26					30.26	
30A	56.03						56.03
	16.95						16.95
	27.37						27.37

APPENDIX B

YIELD OF DIFFERENT VARIETIES OF CANE, PLANT AND LONG RATOONS ONLY (All Fields)

Year	LAHAINA			D 1135			Y. C.		
	Area Acres	T.C.P.A.	T.S.P.A.	Area	T.C.P.A.	T.S.P.A.	Area	T.C.P.A.	T.S.P.A.
1904	3148	72.3	8.76						
1906	3417	71.5	8.07						
1908	3293	74.7	9.44						
1910	3346	68.8	8.66						
1912	2402	68.7	8.68				678	68.3	7.80
1914	1568	67.6	8.67	400	68.0	6.45	894	67.3	7.21
1916	478	82.3	10.18	670	69.5	7.01	1138	71.7	7.81
1905	3142	72.2	9.08						
1907	3256	75.0	9.01						
1909	3115	72.6	9.63						
1911	3445	66.0	8.96						
1913	2153	62.3	8.05	345	69.4	7.11	404	68.2	8.03
1915	1024	66.4	9.00	355	56.2	6.84	1380	57.5	6.90
1917	1061	76.7	9.89	227	75.5	7.64	1045	69.1	7.62
			Yield from selected fields only						
1904	1044	84.3	9.89						
1906	1054	72.5	9.58						
1908	1033	78.7	9.87						
1910	1068	79.3	10.34						
1912	985	76.8	10.16	477	67.4	7.48			
1914	901	74.8	9.72	481	65.7	6.85			
1916	478	82.4	10.18	479	72.1	7.39			
1905	1272	73.4	9.30						
1907	1192	75.4	9.19						
1909	1055	73.8	9.95						
1911	1062	75.1	10.29						
1913	935	74.2	9.69	191	76.0	8.90			
1915	1024	66.4	9.00	191	62.6	7.22			
1917	1061	74.7	9.89	191	64.8	7.05			

NOTE—Lahaina fields selected for study were—

For even years—Fields Nos. 4, 5, 6, 7, 8, 16, 19, 24, 25 and 28.

For odd years—Fields Nos. 2, 13, 15, 17, 18, 19, 23 and 25.

Usually the same fields appear in each successive harvest. In case a field is missing in any particular year, either the field is omitted or the field nearest to it is taken.

APPENDIX C

IRRIGATION WATER PUMPED EACH MONTH

(In million gallons)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1902	819	851	473	600	1266	1360	1562	1656	1583	1707	708	115	12,700
1903	838	804	1385	1192	1443	1598	1688	1823	1753	1670	1260	1250	16,704
1904	1247	156	0	607	1610	1644	1764	1869	1742	1717	1602	949	14,907
1905	1355	1218	1419	1567	1869	1759	1761	1861	1782	1941	1773	1040	19,345
1906	740	1315	1645	1781	1818	1737	1781	1886	1886	1886	1649	95	18,219
1907	0	0	1010	1799	1827	1781	1804	1847	1744	1864	1607	1448	16,731
1908	1498	1317	678	1358	1799	1745	1863	1943	1821	1959	1784	1877	19,642
1909	1180	929	1298	1838	1455	2096	2223	2288	2175	2311	2087	1298	21,183
1910	860	2011	1647	2066	2275	2065	2119	2269	1182	2240	1414	1779	21,927
1911	125	595	1200	1660	1974	2070	2252	2342	2289	2069	2088	1593	20,257
1912	1840	718	1796	1546	2079	1986	1979	2208	2042	2268	1843	1300	21,605
1913	1819	1305	1948	1955	1208	1206	1958	1790	2050	2352	1880	1293	20,764
1914	1143	1244	1320	1298	1867	2315	2414	2475	2162	2529	2264	655	21,686
1915	1894	1656	2229	1896	1739	2192	2331	2395	2120	2418	648	1051	22,569
1916	25	256	1320	2124	2353	2354	2282	2423	2250	2363	2193	1260	21,203
1917	24	507	714	1755	1893	1985	2291	2445	2302	2312	2141	494	18,863
1918	109	436	584	244	2147	2341	2335	2364	2304	2396	1838	521	17,619
1919	1520	1950	2376	2155	2263	1909	2220	2491	2241	2172	2208	2057	25,562
1920	708	903	1934	2031	2313	2303	2257	2293	2255	2320	2144	1063	22,524
1921	30	316	1869	2258	2357	2330	2259	2378	2304	1530	2106	1382	21,119
1922	501	1246	1927	2268	2389	2334	2314	2336	2246	2335	2056	1600	23,552
1923	575	153	1031	1148	2120	2453	2587	2660	2562	2647	2103	1390	21,429
1924	710	1450	1865	416	1930	2400	2638	2740	2589	2615	1864	741	21,958
1925	1068	2053	2137	2210	2476	2557	2519	2547	2598	2362	1479	1021	25,027
1926	1617	1739	2355	1752	2277	1492	2566	2579	2594	2089	1672	1692	24,424
1927	1254	935	1396	930	2181	2514	2618	2758	2650	2693	1700	372	22,001
1928	1061	1791	2016	2209									

APPENDIX D

AREA UNDER IRRIGATION

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1903	4928	5205	5520	4402	4615	4800	5209	5200	5723	6152	6814	6384
1904	6382	5790	5192	5293	5353	5402	5494	5735	5986	6061	6494	6173
1905	5723	5484	5538	5471	5311	5218	5600	6364	6406	6807	6131	6010
1906	5871	5717	5587	5314	5482	5497	6267	6835	6993	7020	6853	6578
1907	6117	6047	6098	5341	5353	5568	5515	6007	6436	6946	6594	6055
1908	5611	5511	5200	4774	4351	4405	4554	5012	5381	6593	6538	6059
1909	5713	5185	4925	5082	4733	4469	4806	5735	6869	7033	6597	6006
1910	5505	5461	5534	5611	5752	5999	6757	6777	7034	6988	6973	6342
1911	6349	5822	5471	5142	4643	4444	4624	6117	6132	6382	5956	5522
1912	5691	5612	5156	4683	4277	4535	5421	6363	6492	7123	7061	6264
1913	6145	5915	5416	5116	4915	4995	5503	6351	6705	7126	6198	6480
1914	6042	5623	5822	5668	5499	5540	6211	6686	7363	7660	7120	6390
1915	6308	6038	5884	5193	5104	5174	5982	6561	6660	7206	7213	6899
1916	6757	6328	6327	6009	5764	5676	5488	5797	6107	6912	7076	6442
1917	6329	5879	5791	5515	5052	4727	5804	6942	7062	7270	7116	6480
1918												
1919												
1920												
1921												
1922												
1923	6331	6314	5729	5777	6185	6235	6871	7546	7620	7513	6953	6357
1924	6254	6211	6076	6228	6598	6407	6236	6887	7520	7567	7062	6558
1925	6563	6848	6711	6496	6503	6320	6987	7790	7790	7686	7159	6496
1926	6289	6441	6431	6315	6734	6429	6916	7471	7672	7667	7347	6936
1927				5150	6135	6918	7399	7405	7829	7747	6704	6147
Average 1903-1917	5965	5708	5564	5241	5081	4763	5549	6166	6490	6885	6716	6272
Average 1923-1927	6359	6454	6237	5993	6431	6462	6882	7420	7686	7636	7045	6479

APPENDIX E

ACRE INCH IRRIGATION WATER PER MONTH

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1903	6.26	5.69	9.24	9.97	11.51	12.26	12.02	12.91	11.28	10.00	6.81	7.46
1904	7.20	0.99	0	4.22	11.08	11.21	11.82	12.00	10.72	10.43	9.08	5.66
1905	8.72	8.18	9.44	10.55	12.96	12.42	11.58	10.76	10.25	10.50	10.65	6.37
1906	4.64	8.47	10.84	12.34	12.21	11.64	10.46	10.16	9.93	9.89	8.86	0.54
1907	0	0	6.10	12.40	12.57	11.78	12.05	11.32	9.98	9.88	8.97	8.81
1908	9.83	8.79	4.80	10.53	15.23	14.59	14.93	14.28	12.46	10.94	10.05	11.41
1909	7.61	6.60	9.71	13.32	11.32	17.27	17.07	14.69	11.66	12.10	11.65	7.96
1910	5.75	13.56	10.96	13.56	14.57	12.67	11.54	12.33	6.19	11.80	7.47	10.33
1911	0.72	3.76	8.08	11.88	15.66	17.15	17.94	14.10	13.75	11.94	12.91	10.62
1912	11.91	4.71	12.83	12.16	17.90	16.13	13.44	12.78	11.58	11.73	9.61	7.67
1913	10.90	8.12	13.24	14.07	9.05	8.89	13.10	10.38	11.27	12.15	11.17	7.34
1914	6.97	8.15	8.35	8.43	12.50	15.39	14.31	13.63	10.81	12.16	11.71	3.78
1915	11.06	10.10	13.95	13.44	12.55	15.60	14.35	13.44	11.72	12.36	3.31	5.61
1916	0.14	1.48	7.68	13.02	15.03	15.27	15.31	15.39	13.57	12.59	11.41	7.20
1917	0.13	3.18	4.45	11.72	13.80	15.46	14.54	12.97	12.00	11.71	11.08	2.81
1918												
1919												
1920												
1921												
1922												
1923	3.35	.90	6.62	7.31	12.62	14.48	13.86	12.98	12.38	12.98	11.14	8.04
1924	4.19	8.60	11.31	2.46	10.78	13.80	15.58	14.66	12.66	12.73	9.72	4.16
1925	5.99	11.04	11.73	12.53	14.03	14.90	13.28	12.05	12.29	11.32	7.60	5.79
1926	9.47	9.95	13.49	10.22	12.46	8.55	13.67	12.72	12.46	10.04	8.39	9.12
1927				6.66	12.09	13.39	13.04	13.72	12.47	12.81	9.34	2.23

APPENDIX F

To find r=coefficient of correlation between range of temperature in October, two years previous, and yield of sugar

Crop year	d_1 Sugar yield departures	d_2 Range of t° departures	d_1^2	d_2^2	$d_1 \times d_2$
1905	—.42	—1.9	.1764	3.61	+ .798
1906	—.36	—3.0	.1296	9.00	+1.080
1907	—.53	—3.8	.2809	14.44	+2.014
1908	—.07	— .6	.0081	.36	+ .042
1909	+.23	+ .5	.0529	.25	+ .115
1910	+.36	+1.5	.1296	2.25	+ .540
1911	+.57	+ .8	.3249	.64	+ .456
1912	+.20	+ .7	.0400	.49	+ .140
1913	—.03	+1.1	.0009	1.21	— .033
1914	—.24	+ .1	.0576	.01	— .024
1916	+.22	+1.2	.0484	1.44	+ .264
1917	+.17	— .2	.0289	.04	— .034
		n = 12	1.2782	33.74	Σ +5.358
			$\sigma_1 = .327$	$\sigma_2 = 1.68$	

$$r = \frac{\Sigma d_1 \times d_2}{n \cdot \sigma_1 \cdot \sigma_2} = \frac{+\ 5.358}{12 \times 1.68 \times .327} = +\ .81$$

APPENDIX G

MONTHLY MEAN MAXIMUM t°

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1901	79.4	77.5	81.4	85.9	85.7	86.7	86.6	87.7	86.5	85.6	82.6	81.2
1902	82.9	78.4	78.2	80.7	81.4	84.0	85.4	86.1	86.0	84.8	81.0	79.0
1903	78.0	76.0	78.0	81.0	83.6	85.0	86.0	86.7	85.8	83.0	81.5	80 7
1904	79.2	75.7	76.3	78.4	82.0	82.9	84.5	85.0	85.2	81.6	78.1	77.5
1905	73.5	75.4	76.1	77.7	79.8	81.5	82.4	82.4	81.9	80.1	79.0	75.6
1906	74.4	76.1	75.7	82.7	84.2	85.8	86.5	86.9	87.1	86.2	83.6	80.3
1907	80.1	80.0	78.6	80.9	84.4	85.9	86.1	86.2	87.0	85.0	82.4	81.5
1908	79.3	80.1	79.6	80.9	83.6	84.3	85.1	86.0	85.4	84.1	82.5	79.2
1909	78.2	78.4	77.0	80.5	83.3	85.4	85.4	86.1	86.3	84.8	83.5	80.1
1910	77.6	78.8	81.0	80.5	82.6	84.0	85.7	86.1	85.6	84.1	81.9	79.3
1911	76.8	77.9	79.5	82.2	83.7	84.6	85.8	87.7	85.7	84.1	82.2	79.7
1912	79.1	79.3	78.6	82.0	84.1	85.1	86.6	87.7	87.4	86.0	82.5	81.1
1913	80.6	79.3	81.5	82.8	83.5	85.2	87.5	88.2	87.7	86.8	83.1	81.2
1914	77.9	80.6	79.5	82.0	83.5	86.1	86.5	88.2	86.5	86.2	82.3	78.8
1915	77.9	77.4	80.2	81.4	84.9	87.0	87.4	88.5	87.9	85.4	81.4	79.3
1916	77.7	80.4	80.1	82.1	82.4	83.4	84.6	84.3	84.4	83.5	81.3	78.8
1917	78.2	78.3	78.9	80.9	83.4	84.7	86.1	86.5	86.7	85.3	82.6	80.6
1918	80.6	78.9	78.6	78.2	82.4	84.1	86.0	86.3	86.4	86.4	83.2	79.6
1919	78.6	80.0	80.0	82.1	83.7	86.0	86.6	87.5	86.6	85.3	83.5	81.2
1920	79.3	81.2	81.1	82.0	84.6	85.5	86.1	87.2	87.5	86.1	82.8	80.2
1921	78.3	80.8	81.2	82.4	83.9	86.9	86.9	86.7	86.4	84.3	82.2	80.3
1922	79.3	78.2	80.4	82.6	83.1	85.6	87.1	86.7	86.5	85.0	82.8	82.3
1923	78.9	79.6	80.3	82.9	85.2	86.8	87.6	88.5	87.9	87.2	83.6	80.3
1924	79.7	81.3	81.3	81.4	84.5	85.7	86.8	86.9	87.3	85.6	83.0	81.7
1925	81.5	84.0	81.8	81.2	83.4	84.6	86.0	86.5	86.4	86.1	83.2	81.5
1926	80.8	81.0	82.1	80.8	84.8	85.7	87.5	87.5	87.4	85.6	83.0	81.9
1927	80.0	81.0	80.9	82.6	84.1	86.0	83.4	86.8	87.2	85.2	81.9	80.3
1928	78.8	80.0	81.5									
Average 1903-1917												
	77.9	78.2	78.7	81.1	83.3	84.7	85.7	86.4	86.0	84.4	81.9	79.6

APPENDIX H

MONTHLY MEAN MINIMUM t°

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1901	67.0	65.2	68.1	68.9	68.5	69.1	69.4	70.6	68.7	68.6	67.1	64.8
1902	62.6	62.5	67.2	64.2	66.7	69.5	70.4	72.0	69.8	67.5	67.0	63.0
1903	61.0	60.0	58.0	65.0	66.4	67.0	71.0	70.9	69.7	68.0	65.3	64.2
1904	64.2	62.7	63.7	65.6	64.2	66.7	67.6	68.7	68.2	67.7	64.1	64.2
1905	55.9	57.3	58.6	62.6	65.7	66.3	68.8	70.4	69.2	67.0	65.8	61.7
1906	61.0	59.9	59.0	64.7	64.6	69.2	69.4	70.5	69.2	68.7	65.3	64.8
1907	64.5	62.2	63.0	61.6	65.1	67.8	68.5	71.2	70.1	67.6	66.2	63.9
1908	61.1	61.8	63.9	63.7	66.0	66.2	67.0	67.9	66.9	65.7	62.5	63.1
1909	60.1	61.3	63.6	62.9	65.4	68.6	69.5	68.2	67.6	67.1	64.0	63.5
1910	62.2	60.1	63.1	64.0	64.6	67.3	67.3	67.9	67.4	66.5	65.8	61.9
1911	62.6	61.6	62.4	65.2	66.2	68.2	69.9	70.7	69.9	66.1	65.1	64.2
1912	61.4	62.0	60.7	64.6	65.6	66.9	68.5	79.5	69.2	69.0	65.4	66.1
1913	62.4	59.9	62.7	65.3	65.6	67.5	68.3	....	69.0	68.1	66.9	61.9
1914	60.6	59.8	61.3	63.6	65.7	68.0	70.1	71.5	71.5	68.1	65.9	61.7
1915	60.7	61.1	61.3	62.8	66.0	68.5	69.8	71.1	69.7	68.7	67.1	65.0
1916	62.6	62.3	64.2	65.1	66.7	67.4	68.0	67.3	67.7	67.4	66.5	63.4
1917	60.4	60.2	63.4	63.7	64.4	66.5	67.2	68.0	67.3	65.9	65.2	63.2
1918	61.5	61.9	61.3	63.8	63.8	66.6	69.5	69.2	67.5	68.2	64.1	63.7
1919	59.2	61.3	60.8	63.3	64.5	66.6	68.4	69.2	66.7	66.1	63.4	61.0
1920	59.7	59.6	61.7	62.7	63.5	63.9	68.4	68.6	68.0	66.6	63.4	62.9
1921	63.1	59.9	61.1	63.1	62.8	67.4	67.3	67.5	67.3	64.5	63.2	62.0
1922	61.1	60.9	61.2	63.2	63.1	64.1	65.5	66.3	66.0	64.7	62.4	59.3
1923	62.5	56.8	60.4	62.2	63.3	63.9	66.6	66.5	66.3	64.4	62.8	61.5
1924	55.2	58.7	58.7	60.7	62.5	62.7	65.1	65.0	64.2	64.3	61.5	59.5
1925	62.1	59.3	59.5	61.7	62.2	63.9	64.9	65.5	62.6	62.4	62.4	62.3
1926	61.0	61.2	61.3	61.0	66.3	67.1	68.0	68.2	68.4	66.9	63.6	64.2
1927	62.2	60.9	64.3	64.1	66.0	67.3	66.0	67.9	67.3	65.8	65.9	63.4
1928	61.7	58.7	61.0									
Average 1903-1917												
	61.4	60.8	61.9	64.0	65.5	67.5	68.7	69.6	68.8	67.4	65.4	63.5

A Contribution to Cane Growth Studies

F. M. Anderson, manager of the Paauhau Sugar Plantation Company, has made an interesting contribution on the subject of cane growth studies. The data were taken in connection with the question of cutting back, in order to have information as to whether cane which was not cut back, under the prevailing conditions, tended to weaken in growth shortly prior to harvest.

Mr. Anderson undertook precise growth measurements of each and every stalk of a 30-foot section of cane row, determining the volume of the stick, not merely the length.

By test he deduced a factor by which cubic inches of cane could be converted to drams and thus it was possible to arrive at a close estimate of the number of tons of cane produced during each month.

Mr. Anderson gave the following account of the tests in a letter to C. Brewer and Company, Ltd., and accompanied it with the chart and tables presented herewith:

A small-sized book might be written from the data obtained and experiences met with in compiling this data monthly, but as we have so many other things to attend to, we will have to submit a brief outline. Your Mr. Cooke and Mr. Johnson have seen some of the preliminary figures and what we were aiming at. Suffice it to say that the growth measurements were obtained from every stalk within a 30-foot section of a row of cane picked at random, except that we satisfied ourselves that an even stand of cane—free from large blanks—constituted the test area, and the measurements were started during December, 1927, and continued thereafter at the same date every month until harvested at the end of December, 1928. The quotation "cut back" versus "not cut back" means that the "cut back" was cut back during May, 1927, whereas the average date of starting the field was March, 1927, giving 21 and 19 months respectively in the comparison.

With the many arguments for and against short cropping, no one has come forward with a clear-cut, definite statement as to what their short crop fields are producing during the month prior to harvesting, either in tons cane or in percentage of the total. This shows definitely just when the crop was made as to cane harvested.

It is easy to visualize in the subscriber's mind, the fact that with a simple mental calculation of 20 months cane, this represents 5 per cent a month and that if we obtained, or it was indicated that we could obtain, 5 per cent additional in the 21st month, you would have a decided gain unless the expense for that month were to be out of proportion to that which resulted during the first 20.

Having this as a basis, therefore, it would seem that if those who desire such data and can ripen their cane at the optimum time—which by the way, we cannot—by putting in numerous such growth measurements to represent certain varieties in certain sections and obtain the value per month under such conditions, they should attain the data for optimum yield over a given period, or in other words, along the same lines as that recommended for varieties, but by the growth measurement method, and assuming that seasons are practically uniform where man controls largely the plant food and water requirements.

It is needless for me to state that it shows, for this test, at least, that cutting back was a decided loss and what the subscriber had in mind when it was put in was because of what appeared to be the tremendous loss resulting from cane gradually dying off after tasseling. The results for this test do not show this, but, just as one test of a variety is

insufficient to prove that such a variety is a super-cane, so in this case I still feel that it requires several seasons' additional data on this same variety of cane and location to prove what loss is resulting from too early starting in the first season's growth and late harvesting, or on the contrary, what loss actually resulted from cutting back to obviate large quantities of dead cane left on the ground and which area was not considered to produce a profitable crop over the short cropping period, or method.

It seems also advisable to comment upon the value in cubic inches per month which with sufficient tests put in could tell us in the short period of one month, about how many tons cane grew per acre per month, from growth measurements taken, as so far the results are fairly uniform as to weight per cubic inch. We might state at this time that we found but very, very little difference between the measurements monthly and those finally obtained when harvested, of each individual stalk recorded. Each stalk was weighed separately and from the grouping on the sheets submitted, you will note the fairly close uniform weight per cubic inch of cane of similar age. Quality of cane was not considered as our laboratory was not in a position to handle the 300-odd stalks of cane that would have been involved to obtain individual samples.

A second letter addressed to the Experiment Station by Mr. Anderson gives an outline as to how his cane growth measurements were arrived at:

An ordinary adjustable-jaw automobile wrench was adapted by our engineer with scale in inches so as to measure the diameter easily as well as the lineal growth. (See Fig. 1.)

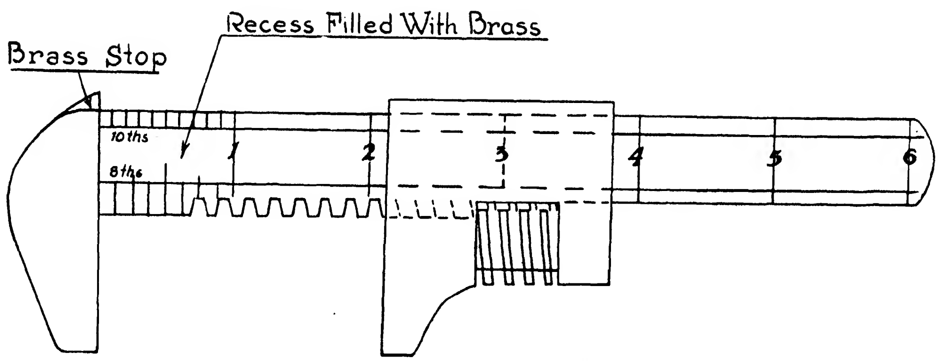


Fig. 1. Gauge for cane measurements, made from a wrench.

When first measurements were taken, each stalk showing cane was tagged with metal tag and the measurement called and recorded up to the base of where the cane would normally be stripped to and a suitable mark made, this being accomplished by one man measuring and calling the number of the stalk and dimensions, and another recording. Later on the computations were calculated and entered against the respective stalks. Subsequent measurements were made monthly in the same manner, and other stalks showing cane, were suitably tagged and measured in the same manner. At the final harvesting measurement, it was planned that any stalk that had previously been measured and was not considered as millable cane, at time of harvesting, on account of being too short in length, would be deducted from the month or months in which previous measurements had been recorded, in order to arrive at net growth by months of millable cane harvested. No such result was met with.

We have recently harvested a similar test, but the results will not be available for at least two weeks yet. Weight per cubic inch has decreased in this other test, but this may be due to poorer juices which we are now having.

METHOD OF OBTAINING FACTOR TO CONVERT VOLUME MEASUREMENTS TO WEIGHT

Data showing age of millable cane = number of stalks, weight of stalk, cubic inch, and percentage, as obtained from growth measurements:

Item 1 Number of stalks millable cane at months before harvested.
2 Same as 1, but showing stalks that died off and from which no millable cane was recovered.
3 Weight of stalks harvested, ounces.
4 Average ounces per stalk.
5 Weight per cubic inch on weight shown by item three—drams.
6 Percentage of total millable cane harvested.

Field 14½B Not Cut Back—Age 21 months—Data from individual stalk measurements and weights when harvested

Months of growth before harvesting	1 See above	2 See above	3 Stalk ounces	4 Ave. stalk	5 Cu. in. drams	Per cent of total crop harvested
21	93	47	3647	38.1	11.6	48.44
19	..	..	....	....	....	.....
17	20	..	929	46.4	10.6	12.35
15	37	..	1551	41.1	10.5	20.60
13	35	1	900	25.7	10.9	11.95
11	23	..	501	21.7	10.7	6.66
9	..	..	....	....	....	.....
Total and Average	208	48	7528	36.1	11.10	100.00

Field 14½B Cut Back—Age 19 months after cut back

19	127	31	3746	29.7	11.6	64.58
17	1	..	8	8.0	8.5	.13
15	5	..	192	38.5	10.5	3.31
13	24	..	949	39.5	10.6	16.36
11	33	..	804	23.0	10.6	13.86
9	7	..	101	14.4	10.5	1.76
7	..	..	....	....	....	.....
Total and Average	..	31	5800	29.4	11.2	100.00

Field 14½B—Cut Back—32 Feet—Dead Cane

1 Stalks	2 Cubic inches	3 Drams per cubic inch	4 Total ounces	5 Equivalent to lbs. per acre	6 Tons per acre	7 Per cent
31	504	11.6	365	5853	2.92	6.27

Field 14½B—Not Cut Back—29 Feet—Dead Cane

1 Stalks	2 Cubic inches	3 Drams per cubic inch	4 Total ounces	5 Equivalent to lbs. per acre	6 Tons per acre	7 Per cent
48	1527	11.6	1107	19256	9.62	14.71

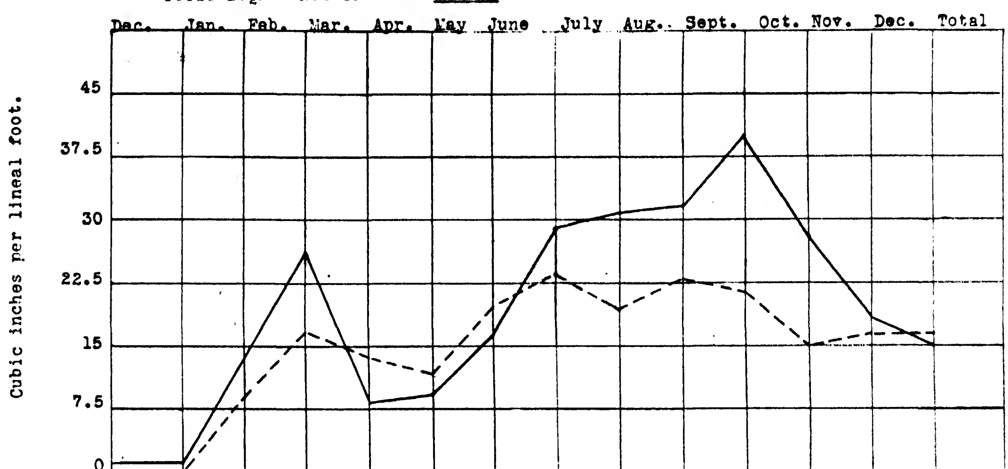
Drams per cubic inch taken from average weight millable cane harvested.

Whilst the averages quoted on sheet showing graph and in Tons Cane per Acre do not agree in any way or even approach the average for the field, it is reasonable to expect that the same relative percentages would apply on monthly growth, irrespective of yield.

(H. P. A.)

Actual Growth Showing Tons of Cane per Acre and
Percent per Month.

Field 14½B - Cut Back ----------
Field 14½B - Not Cut Back ______



	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Cu.in per lineal ft. (Cut Back)	51.74	9.99	17.89	13.59	11.36	18.96	23.16	19.68	22.46	21.80	15.02	16.55	16.55	258.75
" " (Not Cut Back)	100.44	13.15	26.12	8.07	8.85	17.01	28.60	30.55	31.27	40.86	28.91	18.93	14.91	367.69
Tons Cane per Acre per Month (Cut Back)	9.29	1.79	3.21	2.45	2.03	3.41	4.17	3.54	4.04	3.92	2.69	2.98	2.98	46.50
" " (Not Cut Back)	18.04	2.31	4.69	1.44	1.58	3.05	5.13	5.47	5.61	7.34	5.19	2.84	2.67	65.36
% Tons Cane per month (Cut Back)	19.98	3.85	6.91	5.27	4.37	7.31	8.97	7.62	8.69	8.44	5.79	6.40	6.40	100.00
" " (Not Cut Back)	27.60	3.53	7.18	2.20	2.42	4.67	7.85	8.37	8.58	11.23	7.94	4.35	4.08	100.00

Fig 2. The tons cane per acre Cut Back are arrived at by multiplying cubic inches per month at average value 11.2 drams per cubic inch; Not Cut Back by 11.1 drams per cubic inch. Averages of tests from five ditches each of Cut Back and Not Cut Back in this field gave yields of: Cut Back, 56.0 tons; Not Cut Back, 57.6 tons; average of entire Field 14½B, 68.39 tons cane per acre actual mill weights.

International Society of Sugar Cane Technologists

A Communication From the Preparation Committee of the Java Conference

Pasoeroean, Java, 1st December, 1928

The International Society of Sugar Cane Technologists at its meeting in Havana in March, 1927, resolved, at the request of the General Syndicate of Sugar Manufacturers in the Netherlands-Indies, to hold the next Congress at Soerabaia.

The meeting elected Prof. Dr. J. Jeswiet chairman of the Congress and he appointed Dr. V. J. Koningsberger, director of the Agriculture Department of the Java Sugar Experiment Station, as assistant secretary.

Dr. Koningsberger having obtained home leave from August, 1928, to May, 1929, it was decided after conference between Prof. Dr. Jeswiet, who stopped a few days in Java on his return to Holland from New Guinea, and the chairman of the General Syndicate of Sugar Manufacturers in the Netherlands-Indies to entrust the further preparations for the Third Congress to the following Committee:

Prof. Ir. E. C. von Pritzelwitz van der Horst, director of the Technical Department of the Experiment Station, Pasoeroean.

Dr. Ir. P. Honig, director of the Chemical Department of the Experiment Station, Pasoeroean.

Dr. G. Wilbrink, directress of the Cheribon Sub-Experiment Station, Cheribon.

G. Booberg, acting director of the Agriculture Department of the Experiment Station, Pasoeroean.

C. Bruidegom, director of "N. V. Kooy en Co's. Administratiekantoor," Soerabaia.

J. U. F. Benz, treasurer of "Centrale Organisaties in de Suikerindustrie," Soerabaia.

Ir. M. Hoolboom, technical adviser of "Firma Anemaet en Co.," Soerabaia.

Dr. T. van der Linden, head of the Manufacturing Department of "Handelsvereeniging Amsterdam," Soerabaia.

N. J. Peereboom, agricultural adviser of "N. V. Kooy en Co's. Administratiekantoor," Soerabaia.

W. D. B. H. Mulder, secretary of the Board of Direction of the Experiment Station, Pasoeroean.

Above this Committee was constituted an Honorary Committee, consisting of: The Director of Agriculture, Industry and Commerce; the Chief Inspector of the State Railways and Tramways, the Governor of East-Java, the Mayor of Soerabaia, the Consul-General of France at Batavia, the Consul-General of Cuba at

Batavia, the Consuls of the United States of America, England and Japan at Soerabaia, the Chairman of the General Syndicate of Sugar Manufacturers in the Netherlands-Indies and the Chairman of the Royal Institute of Engineers in the Netherlands-Indies.

The provisional Congress program is as follows:

6th June, 1929	Formal reception for members of Congress.
7th " "	Opening of the Congress, general session.
8th " "	General session.
9th " "	Excursion to view irrigation works in the vicinity of Soerabaia.
10th " "	Sectional meeting
11th " "	" "
12th " "	" "
13th " "	General meeting—Termination of Congress.
14th " "	Excursion to Pasoeroean to see the Java Sugar Experiment Station.
15th " ")	
16th " ")	
17th " ")	Excursions to various sugar mills.
18th " ")	
19th " ")	

At the general sessions lectures will be given on the following subjects: Agricultural and chemico-technical development of the sugar industry in Java; co-operation between mill and plantation; irrigation plant, organization and significance for agriculture in general and Java's sugar industry in particular, etc.

For the sectional meetings we have drawn up the following tentative list of subjects to be discussed and several gentlemen have been invited to read papers on them:

1. A method of determining damage by and combating of the most important insect pests of sugar cane.
2. Cytological analysis of the genus *Saccharum*.
3. Present stage of cane breeding work.
4. Experimental gardens and results obtained.
5. Tilling for cane planting.
6. Diffusion combined with mill pressing.
7. Maceration combined with mill pressing.
8. Mill batteries with a large total of rollers.
9. Cane cutters, crushers, shredders, grooving mill rollers.
10. Theoretical basis of juice extraction.
11. Uniformity in reporting factory data.
12. Measuring and weighing cane, raw juice, bagasse, molasses.
13. Boiler Station: types of boiler, steam and feed-water accumulators, choice of steam pressure, bagasse furnaces, recovery of heat from flue gases, control apparatus.

14. Crystallization from impure sugar solutions.
15. Crystallization of non-sugars together with saccharose.
16. Boiling pans.
17. Condensation plants.

The Committee requests that all correspondence pertaining to the Congress be addressed to the Proefstation voor de Java-Suikerindustrie Pasoeroean, Java, Dutch Indies.

Intending participants are requested to notify the Preparation Committee before 1st May, 1929, of their desire to attend the Congress in order that arrangements may be made for residence, etc.

For the Preparation Committee of the Third Congress of the International Society of Sugar Cane Technologists.

PROF. IR. E. C. VON PRITZELWITZ VAN DER HORST,
Chairman;
W. D. B. H. MULDER,
Secretary.

Cane Factory Sanitation*

By W. L. McCleery

The harmful bacteria found in our factories are for the most part brought in with the cane, either adhering to its surface, or in the accompanying soil. We have the High Temperature, or Thermophilic organism, investigated at the Experiment Station, H. S. P. A., by Carpenter and Bomonti†, and the *Bacillus levaniformans* cited by Dr. R. Greig-Smith and commented on at length in studies by D. S. North. There is also the well-known *Leuconostoc mesenterioides* or so-called frog spawn organism together with similar gum formers, also yeasts and moulds of various kinds.

Thermophilic Bacteria: In the investigation noted, these were found to grow in solutions with concentrations to 25° Brix between temperatures of 115° and 164° F. They were acid formers, and capable of bringing about inversion of sucrose at temperatures between 122° and 158° F. They grow luxuriantly at about 148° F., and form spores that withstand boiling an undetermined time. These bacteria were detected in clarified juice, filter press juice, and in sugar from the centrifugal machines.

Bacillus levaniformans: This is widely distributed, and is classed with the potato group of bacilli which are common soil bacteria. It has been shown to be a cause of gum fermentation in juices, and also responsible for deterioration

* Presented at the Seventh Annual Meeting of the Association of Hawaiian Sugar Technologists, Honolulu, October, 1928.

† High Temperature Bacteria in Hawaiian Sugar Factories, *Hawaiian Planters' Record*, 1921, Vol. XXV, p. 171.

of raw and refined sugars while in storage. It has been obtained in almost a pure culture by boiling juice twenty minutes, and incubating at 100° F. Its spores are not killed by continuous boiling, and germinate again on cooling. The sugar destroyed is partly converted into gum. Its limits of growth are about 115° F. and 50° Brix.

Yeasts: They are present not only on the cane, but are transmitted in the air. They grow luxuriantly in low density juices, and can grow in solution to 70° Brix. The most favorable temperature is about 100° F. though some yeasts continue to grow to a temperature of 140° F., and higher. In low density solutions yeasts can destroy sugar more rapidly than any other organism. At higher densities their destructive action becomes slower. They destroy sucrose by alcoholic fermentation with liberation of carbon dioxide, are acid forming, and as fermentation proceeds there is reduction in density of the solution.

Leuconostoc: This is very often present in cane factories, and its presence can easily be recognized by its formation of a slimy, gelatinous material, and colloidal dextran. It grows slowly in acid and neutral juices, but can develop at an enormous rate at an alkaline reaction. Geerligs cites instances where whole tanks of juice have solidified to jelly in fifteen minutes. A number of our factories are from time to time afflicted with this pest, resulting in the formation of very large quantities of this jelly in the limed juice prior to heating. Leuconostoc inverts sucrose rapidly, and also forms lactic and acetic acids. North mentions other gum-forming bacteria, some yielding viscous solutions, and others practically a jelly. They all thrive in dilute juices, with a temperature limit of about 120° F. and are killed by boiling.

Milling Plant Sanitation

In the milling plant there is danger of sucrose loss through yeasts, the *Bacillus levaniformans*, and the High Temperature organism. Their growth is indicated by slime forming on the mill cheeks, in the juice pans, troughs, tanks and anywhere the juice splashes. Any pockets where the flow of juice is impeded by cush-cush collections, such as in our older type of shallow juice pans, are potential sources of infection and sucrose loss.

The mill juice strainers with drag conveyors, even though they are now of all-metal construction, are not self-cleaning, and sour cush-cush collects below the screens. Improvements in strainer construction have been made recently at two factories, and another has done away with the long strainer altogether. The latter factory returns maceration juices to the mills without previous straining by pumps of special construction; the mixed juices being strained through a self-cleaning screen set at an angle. This method has worked very successfully.

In a previous article * the writer gave data on a large number of acidity tests that he made in 1925 during factory inspection visits. Acidity and Brix were determined on the juice from each unit of the milling train, the results being calculated to acidity per cent density, and the increase in percentage noted from mill to mill throughout the train. The factories having the longest trains usually

* Deterioration of Cane Mill Juices from the Aspect of Acidity Increase, *Hawaiian Planters' Record*, 1925, Vol. XXIX, p. 59.

had the greatest acidity increase. The factory that has now done away with the long juice strainer was at that time running one tandem with the strainer and the other without. The per cent acidity increase in the tandem without the strainer was about one-half that in the other tandem.

There is to some extent a natural increase in acidity per cent solids in the juice as expressed from mill to mill. The first expressed juice is mostly from the pith of the cane while that from the latter end of the train is from the harder rind, and more acid. The normal acidity per cent density increase has been taken as 50 to 100 per cent in mill tandems of moderate length and where good sanitary conditions prevail. In mills where little attention has been devoted to cleanliness the increase has been 200 to 400 per cent, or greater. The acidity increase has thus been taken as a measure of bacterial activity. The acidity tests have been continued on factory inspection visits and in general it can be said that improvement has resulted.

Antiseptics have not been recommended on account of the large quantity that would be required, but frequent flushing of the mill beds, cheeks, strainer, receiving tanks, etc., with a high pressure hot water hose, has shown good results. If this is done every three or four hours, with a hose having a small nozzle the dilution of the juice will be hardly noticeable. Hot maceration water to 180° or 190° F. is also recommended.

Mill cleanliness is important not only to reduce undetermined losses in the milling plant to a minimum, but accumulations of sour cush-cush offer excellent breeding spots for the development of the High Temperature organism whose spores can become active later on in the boiling house whenever the temperature drops to a favorable point.

Boiling House Sanitation

Liming Tanks: In the defecation process used in Hawaii the mixed juice is limed before heating. The temperature of the juice in the liming tank is very favorable for the development of Leuconostoc and sucrose losses from this organism are sometimes considerable. If strainers are not used the jelly can clog the pipe line, pump, and heaters, and even the mud outlets in the settling tanks. Cane from certain fields or sections seems to govern the prevalence of this organism. Frequent washing down of the liming tank with a hot water hose followed by spraying with formalin has usually resulted in holding this organism in check. The use of the Fleener continuous liming device which introduces the lime in the pipe line a few feet from the heater is probably the surest way of eliminating this trouble.

Settlers and Evaporators: After the juice passes the heater there is little danger from bacteria unless the temperature drops below 165° F. Tests on juices held over the week-end have proved that if the initial temperature of the limed juice in the settlers is about 180°, with the sides, tops and bottoms of the settlers well insulated, chemical action is retarded and there is very little sucrose loss, provided the temperature does not fall below 165° F.

Filters: In the usual type of filter press, tests have frequently indicated loss through action of the High Temperature organism. Extremely long cycles

of filling and washing should be avoided. The wash-water employed should be reheated to at least 190° F. to insure a temperature of not under 165° F. on the washings.

Syrup: With syrup of good density, 60 Brix or over, there is probably little danger above 140° F. However, inversion from invertase, an enzyme of yeast, is possible up to 150° or 160° F.

Massecuites and Molasses: The density is such that there is little danger of inversion, though moulds sometimes grow on the surface. Molasses of low density readily starts fermentation.

Sugar: Micro-organisms are responsible for heavy loss of sucrose in raw sugar when the moisture content is too high. Extensive work on sugar deterioration has been done at the Experiment Station. It has been found that for safety the moisture should not be over the ratio represented by "25 per cent of (100 minus the polarization)," or a deterioration factor of 0.25. This corresponds to a density of 75 to 80 Brix of the molasses on the sugar crystals. The sugar, as is well known, should not be stored under unfavorable moisture conditions.

SUMMARY

The control of bacteria in our factories seems practicable. In the mill the cane should be ground as soon as possible and slimy accumulation of juice and cush-cush prevented. The temperature of the juices after passing the heaters should be kept above 165° F., and of syrup above 140° F. The moisture in sugar, should be kept low with a deterioration factor of 0.25 or below.

The Colloidal State of Matter*

By Alexander Findlay

Remarkable progress has been made in the study of colloid phenomena in the last decade and our knowledge in many branches of scientific work has been materially extended by these studies. Sugar literature contains frequent references to colloid phenomena relating to both agricultural and factory work. Many writers, unfortunately, use the term "colloid" very loosely and this has added to the confusion which might naturally be expected in connection with a comparatively new and rapidly developing branch of science. Extracts from this paper, presented at the Seventieth Meeting of the American Chemical Society, by Alexander Findlay, of the University of Aberdeen, are presented to clarify this situation. (W. R. McAllep.)

When we crush and grind the ordinary coarse matter, which we can see and handle, we can break it up into smaller and smaller particles. At first these particles

* Sugar, 1928, Vol. XXX., p. 119-120.

can still be seen by the unaided eye, but as the process of grinding is continued they become so small that they can be distinguished only with the help of a lens or microscope. One can carry the process of subdivision of matter still further, so that the particles become too small to be seen even with the aid of the most powerful microscope; and finally reaches the ultimate limit of subdivision, the molecule, beyond which further subdivision is impossible without destroying the chemical nature of the substance. Since the smallest particle of matter directly visible under the microscope is perhaps about a thousand times larger than the simplest molecule, a considerable range of subdivision of matter lies between the limits of the microscopically visible and the molecular states; and it is to this intermediate zone that I have ventured to apply the term "the twilight zone of matter." It is to this range of subdivision of matter that, in more scientific language, the term "colloidal state" of matter is applied.

Not only does matter in the twilight zone of subdivision present many problems of peculiar fascination to the seeker after a fuller knowledge of natural phenomena, but the important role which colloidal matter plays in almost all the diverse fields of human activity appeals also to the man of more practical instincts. In agriculture and in the tanning of leather, in the working of clay for the manufacture of the common brick or for the production of the finest porcelain, in the production of artificial silk and of smokeless ammunition, in the dyeing of textile fibers and in the production of the blue of the sky or the blue of the eye, the colloidal state of matter plays a part. When, further, we recall that Nature has selected matter in the colloidal state to be the vehicle of life and as the medium in which all life processes take place, the importance and interest of a study of the twilight zone of matter become obvious.

It was the Scottish chemist Graham who first discovered a useful method of distinguishing between the molecular state of subdivision and the state of subdivision known as colloidal. Certain substances in solution were found to diffuse through parchment paper or animal membrane, whereas other substances could not do so; and since the substances that did not diffuse through parchment paper were thought to be noncrystallizable and of the nature of gelatin, glue, and similar materials, Graham called them "colloids," from the Greek word for glue. Substance that diffused through parchment paper and existed in solution in the molecular state of subdivision, and salt, for example, were called crystalloids.

Although we recognize the imperfections of Graham's classification, his distinction is of considerable practical importance, for the process of dialysis, discovered by him, gave a means of distinguishing between molecularly dispersed matter and matter in the so-called colloidal state.

Since the characteristic properties of the twilight zone of matter do not depend on the physical state of the finely subdivided matter or of the medium in which the matter is dispersed, we shall find the colloidal properties exhibited not only by colloidal suspensions or emulsions, where we have solid particles or liquid droplets dispersed in a liquid medium, but by smokes (solid particles in a gaseous medium), mists (liquid droplets in a gaseous medium), foams (gas bubbles in a liquid), and so on.

Whereas it could be inferred from the experiments of Graham that the colloidal systems, although apparently homogeneous like a solution of sugar, are neverthe-

less heterogeneous and contain particles which have a magnitude greater than molecular, the actual existence of such particles has been rendered evident by the scattering of light by these particles and the so-called Tyndall effect, and the introduction of the ultramicroscope by Siendentopff and Zsigmondy has enabled the eye to detect the presence of particles of a magnitude of about 0.000006 mm., which is about sixty times the dimensions of a hydrogen molecule. By the use of ultraviolet light and a photographic plate instead of the eye, particles of still smaller dimensions can be detected. This fact has proved of great value in biochemistry in the examination of filterable viruses, as in the case of the virus of cancer according to recent announcements from London.

In the scattering of light by finely divided particles, it is mainly the light of shorter wave length that is scattered and the light reaching the eye is therefore blue. The very fine smoke rising from a wood fire, for example, when illuminated from the side and viewed against a dark background, appears blue, but when viewed against a background of white cloud, that is, by transmitted light, the smoke appears reddish brown in color. In the same way, as Leonardo da Vinci suggested long ago, one may explain the blueness of the sky by the scattering of the sunlight by finely dispersed particles in the atmosphere, or, as is now thought, by the molecules of the atmospheric gases themselves, the background being the blackness of infinite space. The blue color of the eye and the blue colors of feathers are similarly to be explained, as Bancroft has so fully shown, by the scattering of light by finely dispersed matter.

Matter in the colloidal state is therefore matter in a very fine state of subdivision, so that the extent of surface exposed is very large compared with the total volume of the matter. Surface forces, therefore, play a predominant part and bring about changes in the distribution or concentration of matter at the surface of the particles. This change of concentration at a surface, brought about by surface forces, is spoken of as adsorption. We see the effect of adsorption, for example, in the removal of coloring matter from solution by charcoal. By reason of its high adsorbing power charcoal was employed during the Great War in the construction of gas masks for the adsorption of so-called poison gases many of which were not gases at all, but finely subdivided solids, colloidal smokes. Similarly, the recently introduced, highly porous silica gel is used for the recovery of volatile solvents, for the removal, by preferential adsorption, of gasoline from natural gas, and for freeing crude petroleum from deleterious sulfur compounds.

In the production and characterization of colloidal systems, adsorption plays a very important part. By the adsorption of ions from the dispersion medium or from electrolytes present in the solution, the colloid particles acquire an electric charge; and adsorption of the dispersion medium as a whole may also take place to a greater or less extent whereby variation in the general behavior of colloids may be produced. In the case of the so-called suspensoid colloids or hydrophobe colloids, such as colloidal solutions of gold or arsenious sulfide, the dispersed particles may adsorb none or practically none of the dispersion medium, and they therefore exist in suspension as nonhydrated particles, the stability of which is due to their elective charge and to their Brownian movement. In the case of the so-called emulsoid or hydrophile colloids, such as solutions of gelatin or starch, the dispersion medium itself is adsorbed and the stability and properties of such a

colloidal solution are due to this adsorbed water as well as to the electric charge on the particles. The greater the adsorption of the dispersion medium, the more will the stability and properties of the colloidal solution be dependent on this adsorbed medium and the less will they depend on the electric charge.

If the electric charge on a suspensoid colloid is neutralized, agglomeration of the particles followed by precipitation takes place, and this neutralization can readily be effected by the addition of electrolyte. Negatively charged colloid particles will preferentially adsorb the positive ions of the added electrolyte, and positively charged colloids the negative ions, thus neutralizing the charge on the colloid. Although multivalent ions are, in general, according to Hardy's rule, more effective in producing precipitation than univalent ions, recent investigation shows that there is no exact relationship between valency and precipitating power, and that the adsorbility of the ion may exercise an important influence. In the precipitation of colloidal sulfur, for example, the cesium ion is a hundred times more effective than the lithium ion, and has a greater precipitating power than the bivalent ions of zinc, cadmium, or nickel.

The precipitation of fine particles by electrolytes is well illustrated in nature, where the finely divided clay carried by many rivers is deposited when the river water mingles with the sea, thus silting up river mouths and forming deltas.

The electrical charge on a colloid particle may be neutralized not only by the ion of an electrolyte, but also by another colloid carrying an electric charge of opposite sign. Colloids of opposite sign may mutually precipitate each other and produce adsorption complexes, as Bancroft has called them, which simulate chemical compounds. Purple of Cassius, for example, is an adsorption complex of stannic oxide and colloidal gold.

Although mutual precipitation may take place essentially as a result of adsorption, chemical reaction may later occur. As Bayliss has shown, when alumina adsorbs free Congo red acid, which is blue in color, a blue precipitate is formed, but when this precipitate is suspended in water, the blue color changes to red, which is the color of the salts of Congo red.

Adsorption plays an important part in the dyeing of textiles and the staining of animal tissues. Here the negatively charged color ion of the acid dyes is predominantly adsorbed by a positively charged fiber, and a positively charged dye (basic dye) by a negatively charged fiber. In an acid, both the positive charge on the fibers is increased by adsorption of hydrogen ions and adsorption of a negative or acid dye by the fiber is increased. On the other hand, in alkaline solution the negative charge on the fiber is increased and adsorption of a positive or basic dye by the fiber is facilitated. Similarly, addition of a salt giving a readily adsorbed ion, e. g., sulfate ion, will both increase the adsorption of a basic dye and diminish that of an acid dye. In the case of substantive dyes the dye itself is in colloidal solution, and addition of electrolyte in small amount increases the dye adsorption by diminishing the stability of the colloid. Where mordants are used, adsorption takes place, the mordant, a colloid, adsorbing the dye from the dye bath and fixing it on the fiber. It is really the mordant that is dyed, not the fiber. After the dye has been adsorbed secondary changes may take place, leading to the formation of a more stable adsorption complex.

In the case of colloidal solutions of the gelatin type, the stability of the colloid is due mainly to absorbed water or adsorbed dispersion medium, and consequently such solutions are not so sensitive to added electrolytes. Although the addition of small amount of an electrolyte may produce changes in the amount of water adsorbed by the colloid, actual precipitation does not take place until the concentration of added electrolyte is relatively large.

The comparatively great insensitiveness to electrolytes shown by hydrophile colloids of the gelatin type may be transferred to hydrophobic or suspensoid colloids of the colloidal gold type. When gelatin, for example, is added to a colloidal gold solution, the gold is adsorbed by the gelatin and a much greater concentration of electrolyte is required in order to precipitate the gold than is necessary in the absence of the gelatin. The gelatin is said to protect the gold. This so-called protective action, which varies greatly in different hydrophile colloids, is of much importance in many directions. In the Mississippi and Nile rivers the water is always turbid and muddy, owing to the presence of a large amount of colloidal organic matter which stabilizes the fine suspension of clay and soil; and it is only when the rivers reach the salt water of the sea, with its high concentration of salts, that the finely dispersed mud is precipitated, forming deltas. The water of the Ohio River, on the other hand, is at all times clear, owing to the absence of protective colloid and the presence of lime and other salts which act as precipitating agents.

By the use of protective colloids, sparingly soluble substances produced by chemical reaction can be kept in a colloidal state and so prevented from undergoing flocculation and sedimentation. In the production of the photographic plate the silver bromide is prevented from forming a precipitate of coarse particles unsuitable for photographic purposes, and is kept by the protective action of gelatin in a finely divided form.

Many colloids of the hydrophile type, e. g., gelatin, fibrin, etc., when cooled pass into a jelly, owing to a coalescence of the hydrated colloid particles. This jelly may be dried and is then obtained as a more or less horn-like material, such as ordinary dry gelatin. These jellies have the important property of imbibing water, even against very great pressures. This imbibing power is of great biological and agricultural importance. The amount of water imbibed is greatly affected by the presence of electrolytes, being increased by acids and alkalies, up to a certain concentration, but the increased swelling produced by dilute acids is diminished by the addition of salts.

THE HAWAIIAN PLANTERS' RECORD

Volume XXXIII. JULY, 1929 Number 3

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Self-Sterility in Sugar Cane:

Self-sterility, or the inability of a plant to fertilize itself, may be due to several organic or inherent reasons. (1) Both the male and female germ cells may be non-functionable. Such a condition is often found in hybrids resulting from inter-species crossing. (2) The male germ cells (pollen) alone may be abortive. Such a condition is much more common than the first, where both the male and female organs are non-functionable. (3) Both the male and female germ cells may be normal, but those of the same variety are not capable of functioning on one another. Such a situation is known as self-sterility or self-incompatibility. In plants where this phenomenon has been studied intensively it has been found that the pollen tubes formed from the pollen of the same plant grow so slowly down the style that they do not reach the ovules (female germ cells) while they are still receptive. On the other hand, if pollen of this same variety is dusted on the stigmas of another variety it will grow rapidly down the style and fertilize the ovules.

It is a coincidence that the principal varieties of both the pineapple and sugar cane of these Islands fall in this last category.

A study of the self-sterility or self-fertility of the cane varieties used for breeding is most essential in determining which varieties may be safely used as females in a cross. Canes which have normal male and female germ cells but are known to be self-sterile can be conveniently used as either a male or female (or both) in a cross.

Irrigation Studies—Waipio:

The results of an experiment dealing with the relative efficiency of labor and irrigation water where one line, two lines, and four lines are irrigated as a unit from a single pani, appear in this issue. There is a very significant difference in labor and irrigation water requirement per ton of sugar in the different treatments.

The results indicate that the one-line system is the most efficient, the two-line system is less efficient, but allows time for weeding and stripping, while the four-line system is wasteful of water and labor.

Accumulations of Starch in Natal Uba:

There appears to exist a correlation of juice purity of Natal Uba cane with the pH value of the soil on which it is grown. In this variety of cane, grown on an acid soil, excessive accumulations of starch are found in the stalks which may account for abnormal impurities in the juice. It has been shown by others that such large accumulations of starch do not occur in Natal Uba cane grown on an alkaline soil.

Histological examinations were made for these accumulations of starch in the stalks of Natal Uba grown here in Hawaii on a soil with a pH value of 5.3. These examinations were extended to a number of our Hawaiian varieties also grown on an acid soil.

These examinations demonstrate two types of starch accumulations. The first type occurs, without exception, in the upper part of the stalks of all varieties of cane so far examined. The second type occurs only in Natal Uba and only in the mature portion of the stalks of this cane.

These starch accumulations are interesting, not only because of apparent correlation between them and the reaction of the soil and between them and juice purity, but because they are suggestive of causes of varietal variations in the rooting habits of cane and because they may have a bearing on seed selection.

Varieties at Waipio Substation:

In this issue of the *Record* we report the results of a variety test at Waipio. In this test several canes gave as good or better yields than H 109. These are 25 C 19, 25 C 7, 25 C 4 and 20 S 15.

25 C 19 is a fast grower and a fine sugar producer, but is limited to special districts. It will not do in eye spot areas or where weed control is an important factor. It is also subject to wind damage. 25 C 7 and 25 C 4 are more resistant to eye spot and close in better, but are probably not such heavy producers under ideal conditions.

20 S 15 is to be recommended, on account of its splendid juices. We feel that these four canes deserve trial in final field tests, especially in the irrigated districts.

Uba Hybrids at Honokaa Sugar Company:

The systematic efforts of the Honokaa Sugar Company in testing and retesting the early series of 110 Uba hybrids have been largely responsible for the isolation of the few leaders we now have in this group.

The plant and ratoon harvesting results from a large experiment, which included nearly every seedling of the 1924 Uba hybrid series, are reported in this issue. The results are suggestive as to which seedlings of the group should be pursued in further tests.

The seedlings in this test, which showed substantial gains over the D 1135 check, both in plant and first ratoon yields, are: U D 1, 7, 9, 35, 37, 58, 92, 104 and 110. It is interesting to note that the average quality ratio for all the Uba hybrids was 12.8 per cent better in the first ratoon than in the plant, while the average quality ratio for the D 1135 checks was only 2.5 per cent better.

Variety Tests at Olaa Sugar Company:

We are indebted to Raymond Conant for the article in this number on the results obtained from a variety test at Olaa in which P. O. J. 36 and U. D. 1 distinguished themselves by giving large gains over the standard D 1135 as well as all other competitors.

One of these tests was planted in an upper field and another in a middle belt field, where D 1135 is the standard cane. The canes selected for these tests were K 107, K 202, U. D. 1, P. O. J. 979 and P. O. J. 36.

P. O. J. 36 gave a substantial increase in sugar over D 1135 in both areas. This increase amounted to as much as 108 per cent when compared directly with its adjacent plots in the middle belt field.

U. D. 1 gave a greater increase in sugar over D 1135 in the upper lands, but due to its susceptibility to disease, it is a doubtful commercial cane for the upper levels.

Because of its disease resistance P. O. J. 36 is perhaps the better cane for these Olaa areas.

Other varieties tried out against D 1135 in these tests, viz., K 107, K 202 and P. O. J. 979, gave inferior returns as compared with P. O. J. 36 and U. D. 1.

The details with graphs are given in the complete article on page 310.

Phosphoric Acid and Potash:

In a report of the results of Waipio Experiment V, it is shown that for ten years phosphoric acid and potash were not needed. Then distinct indications of the need for potash were shown.

These field results are confirmed by a soil analysis where the available potash supply is shown to be low.

Colloids and the Caking Quality of Raw Sugars:

A report on an investigation of the relation of colloid phenomena to the hardening tendency of raw sugar by A. L. Holven, of the staff of the Crockett Refinery, appears in this issue. Mr. Holven has not been able to find any definite relation.

This work was requested of the Crockett organization because of facilities at Crockett for studying hardening under controlled relative humidity conditions and also because suitable samples could be selected more readily at the Refinery.

Amounts of the Less Essential Plant Nutrients Present in the New Concentrated Fertilizers:

In recent years a great deal of study has been given to the problem of determining the number of elements which are essential for plant growth. Minute traces of bromine, iodine, copper, manganese, fluorine, boron and zinc have been found to be necessary for the growth of many agricultural plants. In connection with studies that are now being carried on by the chemical department, to determine the value of the less usual nutrients for sugar cane, it appeared desirable to know the amounts of these materials that are being added to the new concentrated fertilizers. All the new concentrated materials were found to contain more manganese, copper and zinc than the older forms of fertilizer materials. None of the new products was found to contain boron or iodine. Fluorine was present in approximately equal amounts in the newer and older forms of phosphates.

The Availability of Potash:

In our soil fertility investigations at Kilauea, the studies on potash availability have yielded results somewhat at variance with our general observations on plantation soils. The soils are very low in citric soluble potassium and while most Island soils respond when such deficiencies are "made up," no such response has been obtained at Kilauea. We have identified the form in which potassium, applied as fertilizer, is fixed by Kilauea soils and shown it to be just as reactive chemically as that in a soil from the Waipio substation except for its lesser solubility in 1 per cent citric acid. Theoretically, from the knowledge we have gained of potassium availability in Kilauea soils, the potash which we have shown to be absorbed by the soil should by all means be available to the crop. There appears to be some "outside" factor interfering with assimilation or it may be that at cooler temperatures the cane has a higher potash requirement. We are continuing our studies along this line.

Soil Acidity:

To those who are associated with the sugar industry of the Islands, the lower productive capacity of the mauka fields has always been evident, and it would seem to the casual observer that the mauka lands present the greater opportunity for improving sugar yields. How much of the lower yield is due to temperature and how much to soil fertility can only be conjectured. The principal difference between mauka and makai lands is the greater acidity of the former. Yet, there is

no outstanding evidence of any greatly improved yields from liming the mauka fields to correct this acidity. It is true that in some cases a response to liming has been obtained, but then, again, there are plenty of instances where no response or even injury has resulted.

Our knowledge of the nature and the properties of the compounds causing soil acidity has been greatly clarified during the last few years, and we are now better prepared to interpret the effects of lime on mauka lands.

The soils of Kilauea Plantation are, with few exceptions, acid soils, and also their fertility is low. Then, again, variable effects from liming these soils have been noted, so conditions there are well suited for a study of the influence of lime on the fertility of our acid soils. We have completed a rather extensive study of the nature of the acidity in our soils, the extent to which the bases have been displaced by the soil acidity, and the total capacity which the soils have for fixing bases, which is presented in this number of the *Record*. A number of very significant observations have been made, which adds greatly to our fundamental knowledge of our acid soil types.

Electrodialysis of Hawaiian Soils:

This is a companion article to the report appearing in this issue entitled "Availability of Potash." The manner of determining potash by electrodialysis is discussed, and a description is given of the apparatus employed. The effect of electrodialysis upon a series of Hawaiian soils was studied in some detail. The results obtained were especially considered in regard to the study of potash availability at Kilauea, Kauai.

Some Chemical Reminiscences:

We present in this issue an address delivered by Dr. L. L. Van Slyke at a recent meeting of the Hawaiian Section of the American Chemical Society. Dr. Van Slyke was a pioneer teacher of chemistry in Hawaii. The picture he draws of conditions then existing, is in striking contrast to the close affiliation of science and industry in Hawaii today.

Dr. Van Slyke has been in charge of chemical research at the New York State Agricultural Experiment Station for many years. His investigations have contributed much to our knowledge of the chemistry of milk and dairy products and he has earned an enviable reputation as an authority on this subject.

Self-Sterility in Sugar Cane

By A. J. Mangelsdorf and C. G. Lennox

The failure of a plant to fertilize itself may result from a number of causes. Environmental effects, such as excessive heat or cold, too much or too little moisture, soil toxicity, and so on, may cause failure in seed setting. We are not concerned here with environmental effects like those just mentioned. Only those causes inherent in the plant itself are under consideration. Some of these will be briefly discussed.

1. Failure to develop either viable pollen or viable ovules is a common cause of infertility. Sterility in both sexes often occurs in the offspring of wide crosses. In the animal kingdom the mule is the classical example. The offspring of crosses between different species of sugar cane also tend to be sterile in both sexes. P. O. J. 36, a cane which is rapidly gaining favor in Hawaii, is a cross between *Saccharum officinarum*, variety Striped Mexican, and *Saccharum barberi*, variety Chunnee. Both its ovules and its pollen have proved thus far to be completely sterile.

2. Because of abortive pollen, many plants are unable to fertilize themselves, even though their ovules are functional. This category includes a considerable number of our important canes, among them Lahaina, Tip and Uba. This condition may possibly have had as its cause wide crossing somewhere in the ancestry of the plant. The male germ cells of both plants and animals are much more likely to be abortive as a result of irregularities in reduction division than are the female germ cells. For this reason male sterility as a result of wide crossing is much more common than female sterility. Whenever the pollen of a plant is fertile one may be quite certain of female fertility, except, of course, in the case of dioecious plants. The converse, however, does not hold.

3. The last category to be mentioned, and the one which forms the subject of this paper is self-sterility or self-incompatibility. Here both ovules and pollen are viable, as evidenced by the fact that they function normally when used in crosses with other individuals. The pollen of a given plant, however, is unable to fertilize the ovules of that plant even when dusted on the stigmas in abundance.

Self-sterility is not a rare phenomenon in the plant kingdom. Examples are known in over a hundred different species, representing some thirty-five families. Certain kinds of plums, cherries, and clover are familiar examples of self-sterility.

It is a coincidence that the two principal crops in these Islands, pineapples and sugar cane, are both self-sterile to a high degree. We are informed by members of the Pineapple Station staff that the stigmas of a Cayenne pineapple plant may be covered with pollen from any other Cayenne plant without effect. No seed setting results. All Cayenne plants are, of course, in reality, merely parts of a single plant. Pollinated with pollen from a different pineapple variety, such as Queen, for example, the Cayenne sets seed freely. We have to thank the phenomenon of self-sterility for the absence of seeds in our sliced pineapple.

The situation is similar in H 109. The stigmas of an H 109 tassel covered with its own pollen, or with the pollen from any other H 109 tassel, fail to set seed. Pollinated with pollen from another variety, say D 1135, it sets seed abundantly.

The cause of self-sterility in certain other self-sterile plants in which the phenomenon has been studied intensively, has been found to lie in the fact that the pollen tubes grow very slowly down the styles of the plant which produced them; too slowly, in fact, to reach the ovules while they are still receptive. The same sort of pollen grains, however, applied to the stigmas of another variety, send their tubes down the style with great rapidity and fertilize the ovules within a day or two.

It must be mentioned that in both Cayenne pineapple and H 109 cane the setting of seed in the absence of other varieties does occur, though rarely. The reasons for these occasional exceptions are not known.

H 109 has been cited as an example of almost complete self-sterility. Not all varieties are so highly self-sterile. Indeed, among the canes producing an abundance of pollen there are many gradations between the extreme self-sterility of H 109 on the one hand and the complete self-fertility of H 456 on the other. The following table classifies the varieties thus far studied according to their self-sterility:

RELATIVE SELF-STERILITY OF CERTAIN CANES PRODUCING AN ABUNDANCE OF POLLEN

Classification Based on Preliminary Results and Subject to Revision

A. Partially or Completely Self-Sterile.

H 109	26 C 48	Paia F	25 C 4
H 8965	D 117	Makaweli 3	25 C 7
H 5909	D 1135	Wailuku 2	
H 9811	20 S 16	K 202	
Badila	20 S 17	26 C 189	

(Many others have, to date, given no seedlings on selfing, but must be tested further before their self-sterility can be regarded as definitely established.)

B. Partially or Completely Self-Fertile.

H 456	Wailuku 4	U. S. 666	H 7102
H 27	26 C 113	K 73	H 472
H 9909	26 C 148	K 107	
H 8906	26 C 270	25 C 14	
H 86484	27 C 514	Cavengire	

It is desirable that the degree of self-fertility of all of the more important cane varieties be determined, for practical reasons. If a variety produces a reasonable amount of pollen and is nevertheless self-sterile it may be used either as a male or as a female (or both) in crosses. When two pollen-producing self-sterile varieties are crossed together, each variety will function both as a male and as a female in the cross. The fuzz from both varieties may therefore be planted with full assurance that the resulting seedlings are the result of crossing. The number of tassels required to produce a given number of seedlings may, therefore, be

halved by planting the fuzz from both participants in the cross. Since emasculation is not practicable in sugar cane, a variety which produces pollen may be safely used as a female parent only after the degree of its self-sterility has been determined. If it is relatively self-fertile, too many of its seedlings are likely to be the result of self-pollination, and these are usually worthless except for breeding purposes.

The determination of the degree of self-sterility of a given variety is rather easily accomplished. The procedure consists merely in isolating from possible contamination by foreign pollen a few tassels of the variety in question, taking care to see that all open flowers are first removed.

The relative degree of self-sterility is judged from the number of seedlings obtained. Highly self-sterile varieties, like H 109 or Badila, seldom yield upon selfing more than a half dozen seedlings per tassel, while a self-fertile variety, like H 456, may produce a thousand or more.

Since environmental influences may also result in failure to set seed, the trials on a given variety should be repeated over several seasons, and with tassels from as many different sources as possible, before final conclusions are drawn as to the degree of self-sterility.

Summary

1. Many varieties of sugar cane have sterile pollen and some have sterile ovules. This condition in other plants, and probably in sugar cane as well, results most commonly from wide crossing in the recent ancestry of the plant.
2. Of the varieties of cane having fertile pollen and ovules, a large proportion are more or less self-sterile. Self-sterility has been found in other plants to be due to the failure of the pollen tubes to grow rapidly enough down their own styles to accomplish fertilization before the flower withers.
3. Information as to the degree of self-sterility of the canes intended for breeding is useful in planning crosses between them.

Irrigation Studies—Waipio

COMPARISON OF ONE-LINE, TWO-LINE AND FOUR-LINE IRRIGATIONS

By F. C. Denison and H. R. Shaw

The relative efficiency in labor and water of irrigating one line at a time, two lines as a "U", or four lines zigzag was tested in watercourse plots on H 109 cane, second ratoons, 20 months old. The plots were approximately 0.2 acre in size, and were in series with five replications of the one-line treatment and four replications each of the two-line and four-line treatments. Water was measured

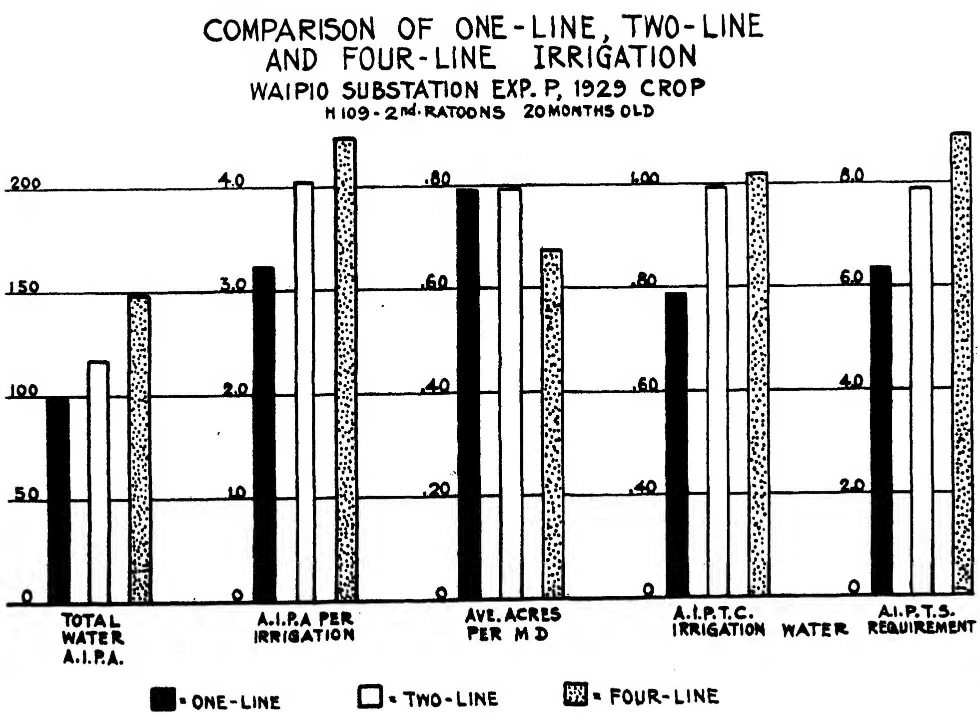
by Great Western meters at the junction of each watercourse and the level ditch; hence all water figures given are *net* water. A record of water used and hours labor required for each plot was carefully maintained. All irrigations were made by one man in order to eliminate the variation between individuals. The irrigator was allowed to follow the usual practice, no extra instructions or supervision being given.

An examination of the results from each watercourse shows little variation in yield, either in cane or sugar. It should be pointed out, however, that such would probably not be the case on land with any considerable slope. The erosive effect of allowing water to cut down the watercourse for four lines or more would undoubtedly lower the yield figures. On level land such a consideration does not enter to as great an extent.

There is a very significant variation in water and labor requirements for the different treatments. The one-line irrigation shows a considerable saving in water, using a total of 70.69 acre inches as against 89.41 acre inches in the two-line system and 98.66 acre inches in the four-line. In the average application per irrigation throughout the crop, the two-line system required over 26 per cent, and the four-line system over 40 per cent more water than the one-line irrigation.

There is relatively little difference in labor requirement indicated by the results from the one-line and the two-line systems. The four-line plots, however, required nearly 15 per cent more labor for each irrigation than the other two treatments.

The most significant basis of comparison is on the irrigation water requirement per ton of sugar. Here, the two-line method demands 25 per cent and the four-line system 40 per cent more than the one-line method.



Conclusions

1. The system of irrigating one line at a time appears to be most efficient in saving labor and water.

2. Results indicate that the two-line "U" system is less efficient than the one-line. In localities where labor and not water is the limiting factor, it is possible that the two-line system may prove more satisfactory. The fact that half the number of *panis* are required and that the longer time required to fill two lines instead of one gives the irrigator an opportunity to weed and strip the watercourse, may make this system more economical.

3. The custom of cutting four or more lines in the watercourse is highly inefficient. It requires a longer length of time for irrigation, is wasteful of water, and gives an uneven distribution of water to the cane. The fact that one irrigator may handle two or three watercourses at one time with this system does not equalize the disadvantage of waste, unequal distribution, and poor condition of the lines due to flooding the upper furrows and improper control of water.

(See accompanying diagram.)

Experiment P

Object: To compare the number of lines irrigated as a unit from a single *pani*, i. e., one line, two lines, and four lines.

Crop: H 109 second ratoons long, 20 months old when harvested.

Layout: Thirteen watercourse plots about 0.2 acre each. Each watercourse water measured by Great Western meter.

Fertilization: Uniform to all plots:

			Total		
Aug., 1927	Oct., 1927	Feb., 1928	N	P_2O_5	K_2O
1000 C. F.	488 A. S.	561 A. S.	300	80	80

Summary of Results

Plots	No. of Plots	Treatment	T. C. P. A.	Q. R.	T. S. P. A.	Total Acre Inches per Acre
A	5	One line	88.96	8.02	11.09	98.76
B	4	Two-line units	90.13	7.99	11.29	117.60
C	4	Four-line units	89.71	8.16	11.01	126.64

EXPERIMENT P

DETAILED WATERCOURSE RESULTS

Plot	Area	Total T. C.	T. C. P. A.	Q. R.	T. S. P. A.	Brix	Polarization	Purity	No. of Irrigations	Total Acre Inches	Average for Crop Acre Inches per Acre	Rain Acre Inches per Acre	Irrigation Acre Inches per Acre	Man Days	Acres per Man Day	Water Requirement Irrigation Only: Acre Inches per Ton Cane	Water Requirement Irrigation Only: Acre Inches per Ton Sugar	Total Water: Acre Inches per Ton Cane	Total Water: Acre Inches per Ton Sugar
1A	.2116	19.128	90.40	7.50	12.05	19.62	17.46	89.3	24	81.26	2.22	27.89	53.37	7.60	0.668	0.59	4.43	0.90	6.74
4A	.2246	20.748	92.38	8.30	11.13	18.80	16.33	86.7	24	99.08	2.95	28.19	70.89	6.35	0.849	0.77	6.37	1.07	8.90
7A	.2201	19.2775	87.59	8.08	10.84	18.90	16.46	87.1	21	105.90	3.71	27.95	77.95	4.95	0.934	0.89	7.19	1.21	9.77
10A	.2088	17.7825	85.17	7.97	10.69	19.18	16.69	87.0	23	96.30	2.98	27.87	68.43	6.15	0.781	0.80	6.40	1.13	9.01
13A	.2556	22.7625	89.06	8.23	10.82	19.27	16.36	85.0	21	111.25	3.94	28.46	82.79	6.10	0.880	0.93	7.65	1.25	10.28
Average A Plots	1.1207	99.6985	88.96	8.02	11.09	19.15	16.66	87.0	22	98.76	3.21	28.07	70.69	6.23	0.792	0.79	6.37	1.11	8.90
2B	.2309	20.103	87.06	7.74	11.25	19.08	16.96	89.0	22	97.93	3.17	28.19	69.74	6.25	0.813	0.80	6.20	1.12	8.70
5B	.2389	22.120	92.59	8.00	11.57	19.10	16.73	87.4	23	132.68	4.54	28.19	104.49	6.75	0.814	1.13	9.03	1.43	11.47
8B	.2138	19.880	92.98	8.03	11.58	18.80	16.49	87.8	22	108.08	3.65	27.89	80.19	6.05	0.777	0.86	6.92	1.16	9.33
11B	.2505	22.0875	88.17	8.18	10.78	18.83	16.33	86.5	22	131.69	4.69	28.48	103.21	6.75	0.816	1.17	9.57	1.49	12.22
Average B Plots	.9341	84.1905	90.13	7.99	11.29	18.95	16.63	87.68	22	117.60	4.06	28.19	89.41	6.45	0.746	0.99	7.92	1.30	10.42
3C	.2175	20.555	94.51	8.01	11.80	18.64	16.53	88.8	22	128.47	4.57	27.89	100.58	7.65	0.625	1.06	8.52	1.36	10.88
6C	.2312	20.6175	89.25	7.98	11.18	19.35	16.68	86.5	22	123.65	4.35	27.95	95.70	7.35	0.692	1.07	8.58	1.38	11.06
9C	.2226	20.3425	91.39	8.26	11.06	18.70	15.66	86.4	22	128.27	4.56	27.89	100.38	7.35	0.666	1.10	9.08	1.40	11.60
12C	.2431	20.5125	84.38	8.43	10.01	18.37	15.86	86.4	22	126.20	4.48	28.98	98.66	7.51	0.669	1.10	8.96	1.41	11.50
Average C Plots	.9144	82.0275	89.71	8.16	11.01	18.76	16.18	87.0	22	126.64	4.45	28.21	98.99	7.70	0.693	1.16	9.79	1.49	12.61

Accumulations of Starch in the Stalks of Natal Uba Cane Grown on Acid Soil

By D. M. Weller

At the annual conference of the Cuban Sugar Technologists in 1928, J. Alfaro of Palmira pointed out an interesting correlation of juice purity of Natal Uba cane with the pH value of the soil on which it was grown. E. Haddon, chemist, Incomati S. E., Ltd., Xinavane, Portuguese East Africa, had previously pointed out that in Uba cane (Natal) grown on acid soil there were accumulations of starch, while in that grown on alkaline soils there were not. Mr. Alfaro writes in the *Proceedings of the Second Annual Conference of the Association of Sugar Technologists of Cuba:*

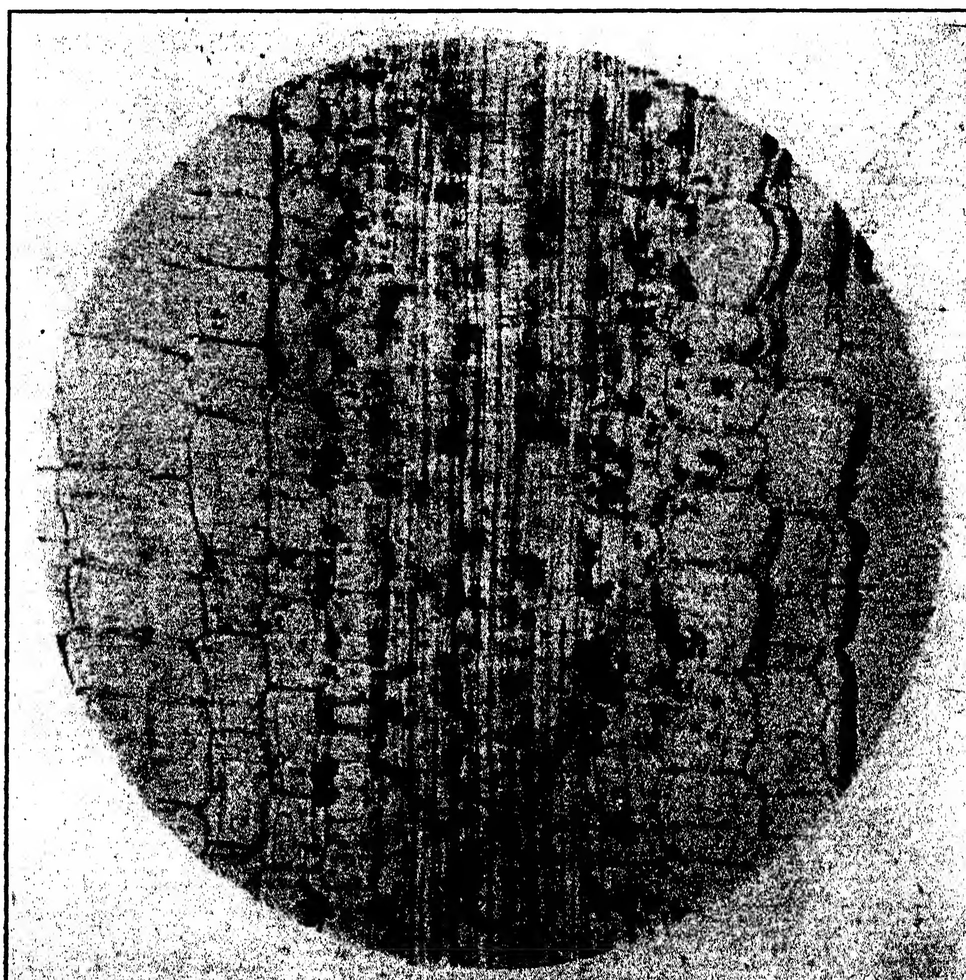


Fig. 1. Longitudinal section of stalk of H 109 cane showing accumulations of starch in the cells adjacent to the vascular bundles. This section was taken from the region of the stalk immediately above the node subtended by a functioning leaf. The pH value of the soil on which this cane was grown was 5.3. (X140)

However, in August, 1927, the publication *Sugar* published a resume of a work which Mr. Haddon had in turn published in the *Revue Agricole de Maurice*, in which he came to the conclusion that the Uba cane grown there on acid soil produced considerable quantities of starch, while on alkaline soils there were no indications of it, attributing to the starch the principal cause of the impurities in the juice of the Uba cane. This observation of Mr. Haddon was also later confirmed by Feuilherade, according to *Sugar* in the January issue of the present year (1928), as well as by de Sornay, according to the *International Sugar Journal* of the month of November, 1927.

In view of these facts some histological examinations were made for the accumulations of starch in the stalks of Natal Uba grown here in Hawaii on a soil with a pH value of 5.3. These examinations were extended to a number of our Hawaiian varieties also grown on an acid soil with a pH value of 5.3. These tests were made by cutting microtome sections from pieces of the stalk, treating them with iodine solution, and studying them under the microscope. These pieces of the stalk were taken from the region immediately below the node, from the nodal region, and from the region immediately above the node. In each case the node selected was one high enough on the stalk to be subtended by a functioning leaf. A test was considered positive when there was an accumulation of starch grains within the parenchyma cells, such as is pictured in Figs. 1 and 2. When the tissue was perfectly clear showing no starch grains whatsoever the test was called negative.

The results of such tests on several varieties of cane are shown in Table I:

TABLE I

Showing the results of tests for the accumulation of starch in the stalks of several varieties of cane grown on a soil with a pH value of 5.3. Each node was from a region high enough on the stalk to be subtended by a functioning leaf. A minus sign indicates that the test was negative and a plus sign that it was positive.

Variety	Below Node	Node	Above Node
H 109	—	—	+
H 109*	—	—	+
Hawaiian Uba	—	—	+
Natal Uba	—	—	+
Porto Rico Uba	—	—	+
D 1135	—	—	+
U. D. 1	—	—	+
P. O. J. 36	—	—	+

From the data shown in Table I it is seen that, for a node subtended by a leaf, in no case was there an accumulation of starch grains, either below or in the node itself, but that without exception there was an accumulation of starch above the node. This was true for H 109 canes which were grown on soils with pH values of 5.3 and 7.5.

In the same way these tests were made using nodes from a different region of the same stalks. These nodes were selected so that each one was about two

* Grown on a soil with a pH value of 7.5.

Fig. 2. Longitudinal section of the stalk of H 109 cane at the same region as that of Fig. 1. (X745)

feet below the lowest functioning leaf of that stalk. The results of these tests are shown in Table II:

TABLE II

Showing the results of tests for the accumulation of starch in the stalks of several varieties of cane grown on a soil with a pH value of 5.3. Each node was taken from the mature portion of the stalk about two feet below the lowest functioning leaf. A minus sign indicates that the test was negative and a plus sign indicates that it was positive.

Variety	Below Node	Node	Above Node
H 109	—	—	+
H 109*	—	—	+
Hawaiian Uba	—	—	—
Natal Uba	+	+	+
Porto Rico Uba	—	—	—
D 1135	—	—	+
U. D. 1	—	—	+
P. O. J. 36	—	—	—

* Grown on a soil with a pH value of 7.5.

From the data shown in Table II it is seen that for the varieties H 109, D 1135, and U. D. 1 the same results were obtained for nodes of the mature part of the stalk as for those subtended by a functioning leaf, i. e., accumulation of starch occurred neither below nor in the node, but in the tissue above the node. For the Hawaiian Uba, the Porto Rico Uba, and the P. O. J. 36 there was no accumulation below the node, in the node, or above the node. *The Natal Uba showed accumulations in all three places.*

It is to be noted that all accumulations of the starch grains in the tissue above the nodes subtended by leaves occurred in the parenchyma cells adjacent to the vascular bundles. In several instances as many as three rows of cells surrounding the bundles showed these accumulations (Figs. 1 and 2). This was true also of accumulations in the tissue above the nodes taken from a point on the stalk about two feet below the lowest functioning leaf for all of those varieties where accumulations occurred, *except that of Natal Uba.* In this variety a marked difference

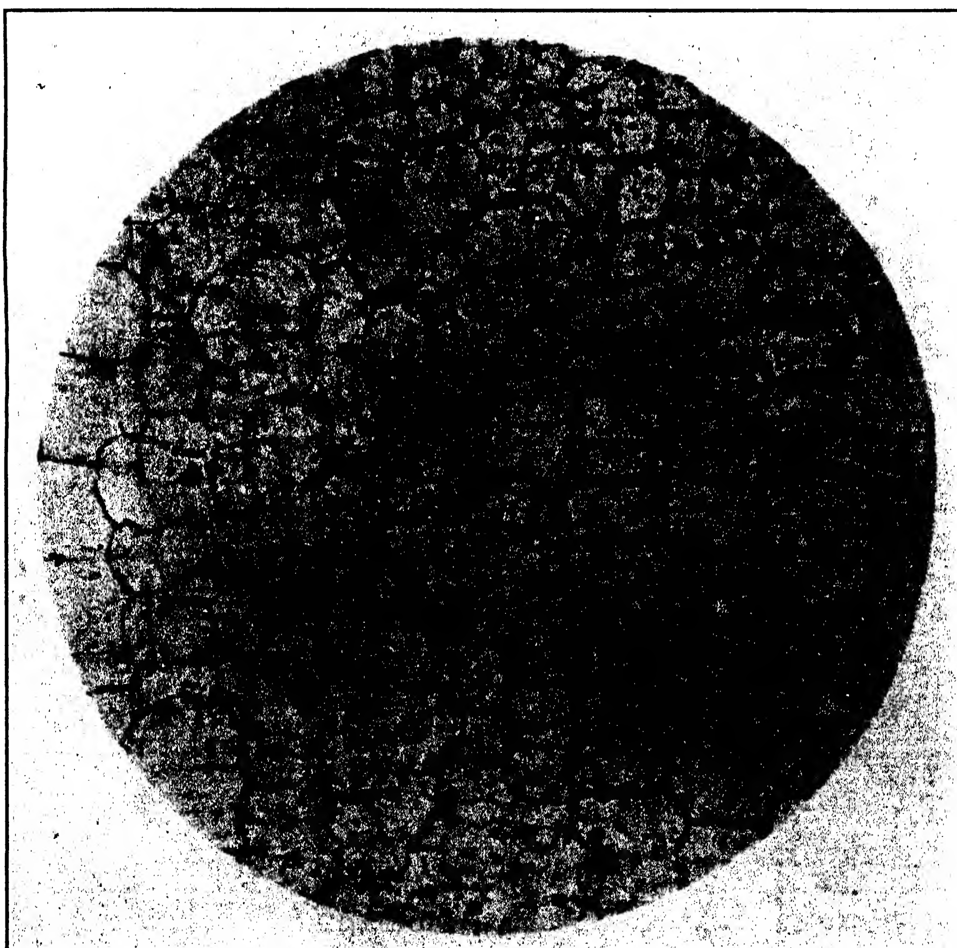


Fig. 3. Longitudinal section of Natal Uba cane showing accumulations of starch grains in all of the parenchyma cells, both in those adjacent to the vascular bundles and in those lying between the bundles. This section was taken from the region of the stalk immediately below a node. The pH value of the soil on which this cane was grown was 5.3. (X140)

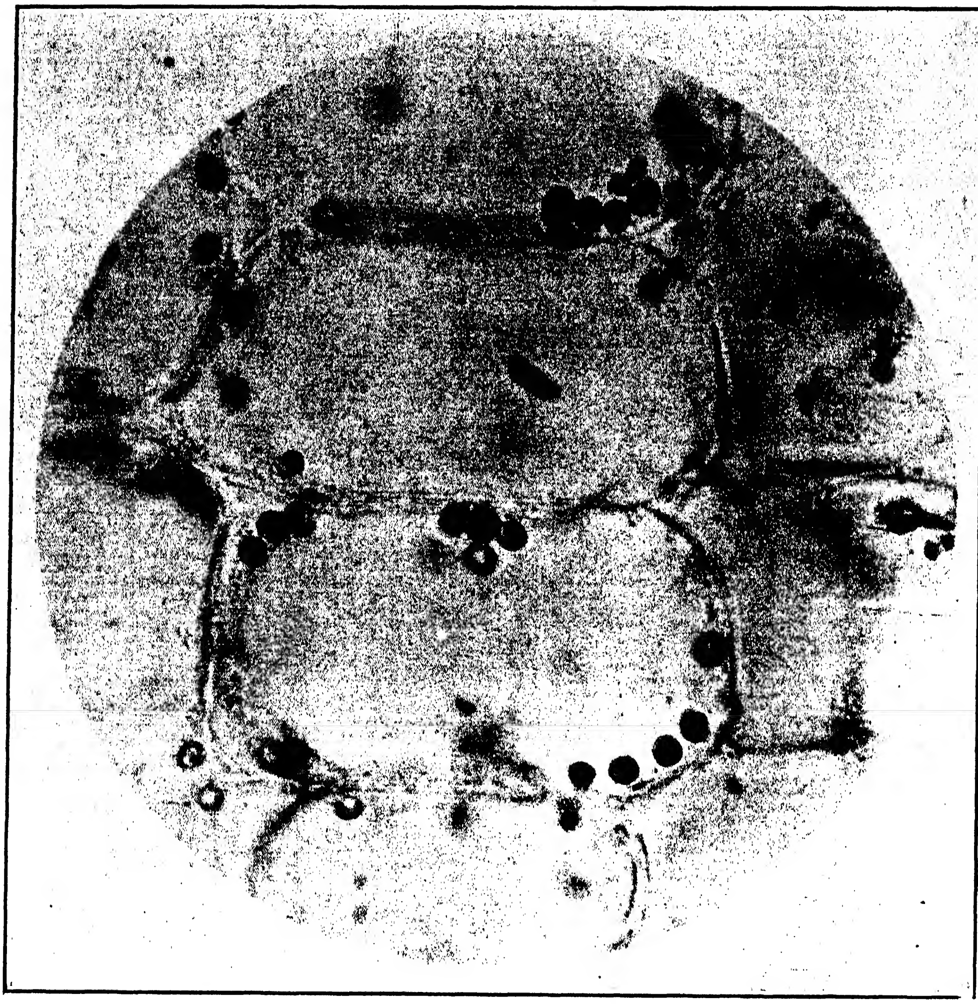


Fig. 4. Longitudinal section of the stalk of Natal Uba cane at the same region as that of Fig. 3. (X745)

was noted in that such accumulations occurred in all of the parenchyma cells, both in those adjacent to the vascular bundles and in those lying between the bundles. (Figs. 3 and 4.)

Dr. A. J. Mangelsdorf is growing Natal and Hawaiian Uba cane in large concrete tubs, using a neutral soil (pH value of 7.5) and the same soil with pH values adjusted to 5.3 and 8.5. In the same way as described above, tests for the accumulations of starch will be made on the stalks of these canes grown in soils with three different pH values. If the pH value of the soil is the direct or indirect cause of these accumulations of starch, these tests should show marked differences in the accumulations.

There are, then, two distinct types of these starch accumulations in the cane plant. The first type occurs only *above the nodes* in the first two or three layers of parenchyma cells surrounding the vascular bundles.

The second type occurs in all of the parenchyma cells, both in those immediately adjacent to the bundles and in all of those cells lying between the bundles.

The first type occurs without exception in all varieties of cane so far examined in the region of the stalk subtended by functioning leaves. This was true for H 109 grown on both an acid and an alkaline soil. This type occurs also in the mature portions of H 109, D 1135 and U. D. 1.

The second type occurs only in Natal Uba cane and only in the mature portions of the stalks of this cane. In this case such accumulations occur not only above the node but below the node and in the node as well. In the young portions of the stalks of this cane, i. e., in those subtended by functioning leaves, the accumulations are, as was pointed out above, of the first type.

In the mature portions of the stalks of Hawaiian Uba, Porto Rico Uba, and P. O. J. 36 there were no accumulations of either type.

These starch accumulations are interesting, not only because of whatever correlation exists between them and the reaction of the soil and between them and juice purity, but because they suggest other correlations.

It has been shown (1, 2) that the shoots of roses grow much more rapidly and develop a much larger and more vigorous root system if the nodes of the cuttings from which they grew showed starch accumulations. These facts are suggestive of causes of varietal variation in the rooting habits of cane and may have a bearing on seed selection.

LITERATURE CITED

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Cane Varieties at Waipio Substation

WAIPIO EXPERIMENT S

By J. A. Verret

The cane in this test was planted in September, 1927, and harvested in March, 1929. Better yields would have been obtained had it been possible to hold the field over two or three months longer.

In the layout every other plot was planted to H 109. All plots received uniform treatment.

The results obtained are summarized:

Variety	No. of Plots	Tons per Acre Cane	Tons per Acre Q. R.	Tons per Acre Sugar	Per Cent Gain or Loss in Sugar
25 C 4.................	3	77.4	8.3	9.3	+ 15
H 109 checks...........	6	74.9	9.2	8.1	
25 C 7.................	3	82.9	9.2	9.0	+ 11
H 109 checks...........	9	73.3	9.1	8.1	
25 C 19................	3	76.4	7.6	10.0	+ 22
H 109 checks...........	9	70.0	8.5	8.2	
25 C 32................	3	58.8	7.3	8.0	— 4
H 109 checks...........	9	68.9	8.3	8.3	
25 C 34................	3	59.2	9.3	6.4	— 28
H 109 checks...........	9	69.3	7.8	8.9	
20 S 15................	3	67.8	7.0	9.7	+ 7
H 109 checks...........	9	69.8	7.7	9.1	
20 S 17................	3	60.3	8.1	7.4	— 21
H 109 checks...........	9	71.4	7.6	9.4	
20 S 18................	3	73.8	8.9	8.2	— 7
H 109 checks...........	9	68.6	7.8	8.8	
20 S 19................	3	50.2	7.8	6.4	— 27
H 109 checks...........	6	68.6	7.8	8.8	

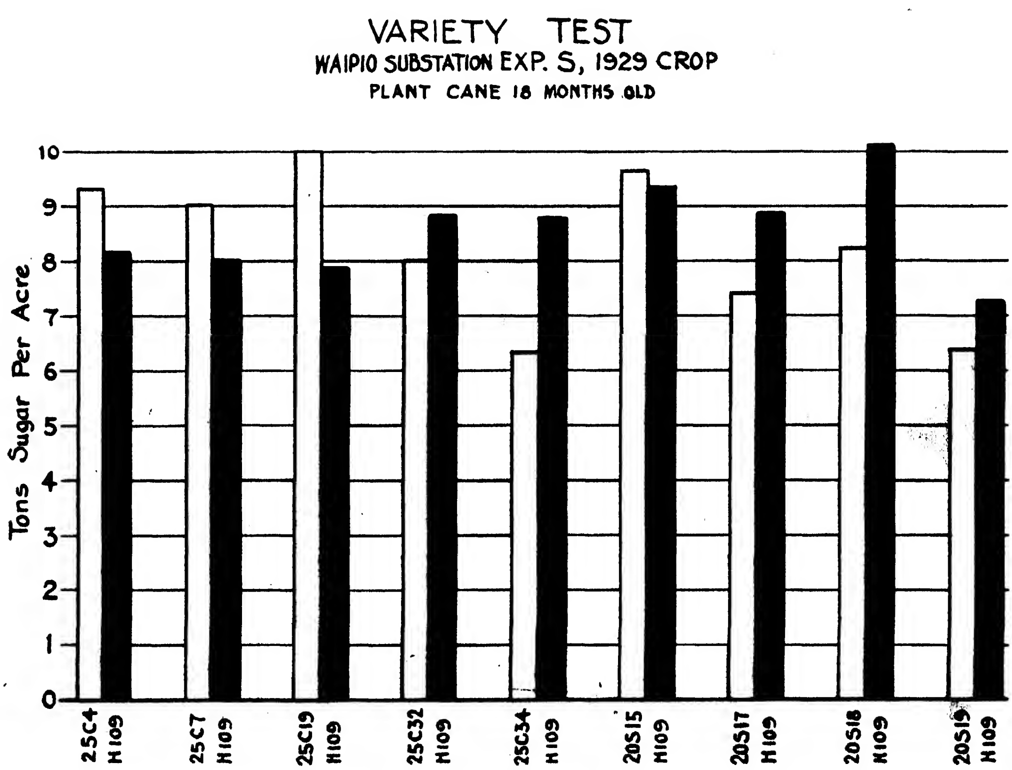


Fig. 1

Several of the above canes give indications of being able to compete with H 109 in certain areas. (See Fig. 1.)

In this test at Waipio 25 C 19 was the most consistent performer. In all cases it produced more cane and sugar than any adjoining H 109 plots. As we had nine H 109 plots adjoining the 25 C 19 these results can be regarded as being significant.

A summary of the reports on agricultural qualities of this cane shows seven cases where it is superior to H 109, nine where it is equal and one where it is inferior. In regard to Yellow Caledonia four of the reports show superiority and three equality. Reports from D 1135 areas show one superior and one inferior observation. In Tip regions it is reported on a par with Tip once, and inferior once.

In the wet districts it seems to have somewhat poorer juices; its susceptibility to eye spot and its open habits of growth do not recommend it for these districts.

VARIETY TEST

WAIPIO SUBSTATION EXP. S, 1929 CROP

PLANT CANE 18 MONTHS OLD.

Div. No.	14	13	12	11	10	9	8	7	6	Plot No.
1	20S19	H109	20S17	H109	25C34	H109	25C19	H109	25C4	Variety
	50.6	81.5	57.7	70.7	58.2	70.5	81.8	70.3	78.1	Cane
	7.83	7.62	8.13	7.30	9.33	7.90	7.64	8.8	8.3	Q.R.
	6.5	10.7	7.1	9.7	6.2	8.9	10.7	8.0	9.4	Sugar
2	H109	20S18	H109	20S15	H109	25C32	H109	25C7	H109	
	61.7	70.0	71.1	67.8	69.7	55.7	67.9	81.5	74.1	
	8.05	8.98	7.74	7.02	8.05	7.33	8.84	9.2	9.7	
	7.7	7.8	9.2	9.7	8.7	7.6	7.7	8.9	7.6	
3	20S19	H109	20S17	H109	25C34	H109	25C19	H109	25C4	
	53.0	84.1	62.7	73.6	63.8	70.6	74.0	69.6	74.2	
	7.83	7.62	8.13	7.30	9.33	7.90	7.64	8.8	8.3	
	6.8	11.0	7.7	10.1	6.8	8.9	9.7	7.9	8.9	
4	H109	20S18	H109	20S15	H109	25C32	H109	25C7	H109	
	67.6	77.1	68.5	67.7	72.3	61.5	73.5	80.4	83.0	
	8.05	8.98	7.74	7.02	8.05	7.33	8.84	9.2	9.7	
	8.4	8.6	8.9	9.6	9.0	8.4	8.3	8.7	8.6	
5	20S19	H109	20S17	H109	25C34	H109	25C19	H109	25C4	
	46.6	65.6	60.6	60.5	55.5	65.7	73.3	72.0	80.2	
	7.83	7.62	8.13	7.30	9.33	7.90	7.64	8.8	8.3	
	6.0	8.6	7.5	8.3	5.9	8.3	9.6	8.2	9.7	
6	H109	20S18	H109	20S15	H109	25C32	H109	25C7	H109	
	50.8	74.1	66.9	67.8	70.5	59.2	68.0	86.9	80.9	
	8.05	8.98	7.74	7.02	8.05	7.33	8.84	9.2	9.7	
	6.3	8.3	8.6	9.7	8.8	8.1	7.7	9.4	8.3	

Fig. 2

In the dry districts its juices are as good or better than H 109.

In the limited areas to which it is adapted we feel that in most cases it will outyield H 109 and suggest that it be planted in final tests with H 109 and in reasonable field areas to test its reaction to regular plantation conditions.

A report from Pioneer Mill Company indicates that it suffers from wind damage, the tops being broken off. We therefore recommend that this cane be not planted in eye spot areas or in wind-swept fields.

25 C 4 and 25 C 7 also consistently outyielded the surrounding checks of H 109 in tonnage, especially the latter. This cane has received many favorable reports in the Caledonia regions. It has the ability to close in, and ratoon fast. Both canes are resistant to eye spot.

Another cane we should like to see tried out in final tests on irrigated plantations is 20 S 15. This is a Striped Mexican seedling. It is very resistant to eye spot. At Waipio it has consistently given good juices.

In 1927, it was first in quality out of sixteen, with a quality ratio of 7.96. The average of three H 109 plots in the same field was 9.36, and the average for all varieties was 9.27. This was plant cane eighteen months old when harvested in January. You will note that in the harvest this year in another field, it was again first with a quality ratio of 7.0, against a field average of 7.93, and 7.7 for adjoining H 109. In both of these harvests it has equalled H 109 in sugar production with the advantage of producing it from less cane. (See Fig. 2.)

Notes taken on the ratooning in this field one month after harvesting show that 25 C 7, 20 S 15 and 20 S 19 are all coming up faster than H 109, with 25 C 4, 25 C 19 and 25 C 34 about on a par with H 109.

The detailed plot yields for this year's harvest are given:

Variety	Plot	Area	T. C. P. A.	T. S. P. A.	Brix	Pol.	Pur.	Q. R.
25 C 4	6.1	.042	78.1					
	6.3	.042	74.2					
	6.5	.036	80.2					
		.120	77.4	9.33	19.7	16.61	84.3	8.3
H 109	6.2	.042	74.1					
	6.4	.042	83.0					
	6.6	.042	80.9					
		.126	79.3	8.18	17.4	14.38	82.8	9.7
25 C 7	7.2	.043	81.5					
	7.4	.043	80.4					
	7.6	.043	86.9					
		.129	82.9	9.01	18.2	15.22	83.5	9.2
H 109	7.1	.043	70.3					
	7.3	.043	69.6					
	7.5	.036	72.0					
		.122	70.5	8.02	18.3	15.61	85.2	8.8
25 C 19	8.1	.041	81.8					
	8.3	.041	74.0					
	8.5	.039	73.3					
		.121	76.4	10.0	19.7	15.84	80.2	7.64

Variety	Plot	Area	T. C. P. A.	T. S. P. A.	Brix	Pol.	Pur.	Q. R.
H 109	8.2	.041	67.9					
	8.4	.041	73.5					
	8.6	.041	68.0					
		.123	69.7	7.89	17.9	15.23	84.9	8.84
25 C 32	9.2	.044	55.7					
	9.4	.044	61.5					
	9.6	.044	59.2					
		.132	58.8	8.03	20.0	17.86	89.5	7.33
H 109	9.1	.044	70.5					
	9.3	.044	70.6					
	9.5	.039	65.7					
		.127	69.9	8.85	19.2	16.79	87.5	7.90
25 C 34	10.1	.041	58.2					
	10.3	.041	63.8					
	10.5	.039	55.5					
		.121	59.2	6.35	18.1	14.67	81.7	9.33
H 109	10.2	.041	69.7					
	10.4	.041	72.3					
	10.6	.041	70.5					
		.123	70.8	8.80	19.1	16.53	86.8	8.05
20 S 15	11.2	.042	67.8					
	11.4	.042	67.7					
	11.6	.037	67.8					
		.121	67.8	9.66	20.6	18.59	90.3	7.02
H 109	11.1	.042	70.7					
	11.3	.042	73.6					
	11.5	.042	60.5					
		.126	68.3	9.36	19.7	17.91	89.9	7.30
20 S 17	12.1	.039	57.7					
	12.3	.039	62.7					
	12.5	.035	60.6					
		.113	60.3	7.42	17.3	15.93	91.7	8.13
H 109	12.2	.039	71.1					
	12.4	.039	68.5					
	12.6	.039	66.9					
		.117	68.9	8.90	19.1	16.98	89.0	7.74
20 S 18	13.2	.041	70.0					
	13.4	.041	77.1					
	13.6	.037	74.1					
		.119	73.8	8.22	18.1	15.13	83.4	8.98
H 109	13.1	.041	81.5					
	13.3	.041	84.1					
	13.5	.041	65.6					
		.123	77.1	10.12	19.6	17.29	88.3	7.62

Variety	Plot	Area	T. C. P. A.	T. S. P. A.	Brix	Pol.	Pur.	Q. R.
20 S 19	14.1	.045	50.6					
	14.3	.045	53.0					
	14.5	.040	46.6					
		.130	50.2	6.41	19.7	16.98	86.3	7.83
H 109	14.2	.045	61,7					
	14.4	.045	67.6					
	14.6	.045	50.8					
		.135	58.7	7.29	19.7	16.75	84.8	8.05

Uba Hybrids at Honokaa Sugar Company

Honokaa Sugar Company has kindly supplied the following yield figures on a number of the Uba hybrids.

The test was conducted in Field 101, at an elevation of 400 feet, under overhead irrigation. Each plot contained 1/20th acre. Alternate plots were checks of D 1135:

	1927 Crop—19 Months Old Plant Cane					1928 Crop—18 Months Old First Ratoons					Plant and First Ratoons	
		Tons per Acre		T. S. P. A.			Tons per Acre		T. S. P. A.		T. S. P. A.	
Variety	Q. R.	Cane	Sugar	Gain	Loss	Q. R.	Cane	Sugar	Gain	Loss	Gain	Loss
D 1135	14.1	86.4	6.13			13.5	52.1	3.85				
U. D. 1......	9.2	100.4	10.91	3.63		10.6	111.7	10.57	6.22		9.85	
D 1135	11.5	97.1	8.44			12.9	61.7	4.78				
U. H. 2.......	34.2	83.3	2.46		6.29	18.4	60.6	3.29		2.43		8.72
D 1135	11.9	107.9	9.06			11.4	75.9	6.66				
U. H. 4......	12.4	126.6	10.21	2.43		14.7	83.9	5.71	0.33		2.76	
D 1135	13.1	85.3	6.51			12.8	52.5	4.10				
H. U. H. 6...	19.2	98.6	5.13		2.13	15.8	96.4	6.10	1.34			0.69
D 1135	11.0	88.1	8.01			10.4	56.4	5.42				
U. D. 7.......	13.2	117.3	8.89	2.17		12.6	91.5	7.26	2.61		4.78	
D 1135	13.5	73.4	5.44			11.2	43.5	3.88				
U. D. 9.......	13.0	107.5	8.27	2.96		12.4	115.2	9.29	4.94		7.90	
D 1135	16.4	85.0	5.18			11.3	54.6	4.83				
U. D. 13.....	14.6	91.3	6.23		0.31	12.7	68.9	5.43	0.37		0.06	
D 1135	11.7	92.5	7.90			12.1	64.0	5.29				
D 1135	14.5	81.5	5.62			14.8	56.1	3.79				
U. D. 14......	36.2	105.9	2.92		2.42	17.8	107.9	6.06	2.35			0.07
D 1135	16.0	81.1	5.07			13.5	49.1	3.64				
U. D. 21......	26.9	111.6	4.15		2.10	12.7	111.7	8.79	3.94		1.84	
D 1135	12.9	95.8	7.43			13.0	78.8	6.06				
U. D. 25......	11.5	98.5	8.56	1.97		19.0	85.3	4.49		0.96	1.01	
D 1135	13.1	75.3	5.75			9.7	46.9	4.84				
U. D. 26......	14.8	85.3	5.87	0.29		11.5	68.2	5.93	1.00		1.29	
D 1135	13.7	74.2	5.41			12.2	56.3	5.03				
U. D. 30......	13.1	104.0	7.93	2.76		14.5	85.5	5.90	1.44		4.17	
D 1135	13.5	66.8	4.93			13.2	52.3	3.96				
U. D. 35......	16.3	129.1	7.91	2.53		13.7	131.9	9.62	5.64		8.17	
D 1135	16.4	94.4	5.74			12.2	49.0	4.01				
U. D. 39......	12.5	73.9	5.81		0.60	10.8	79.9	7.40	2.40		1.80	
D 1135	11.7	83.4	7.09			11.6	69.4	5.98				

Variety	1927 Crop—19 Months Old Plant Cane Q. R.	Tons per Acre Cane	Tons per Acre Sugar	Gain T. S. P. A.	Loss T. S. P. A.	1928 Crop—18 Months Old First Ratoons Q. R.	Tons per Acre Cane	Tons per Acre Sugar	Gain T. S. P. A.	Loss T. S. P. A.	Plant and First Ratoons Gain T. S. P. A.	Loss T. S. P. A.
D 1135	10.2	102.0	10.00			12.7	57.9	4.56				
U. D. 56	12.5	105.9	8.47	0.57		13.4	90.2	6.73	2.42		2.99	
D 1135	14.8	85.7	5.80			13.3	53.9	4.06				
U. D. 58	11.4	118.3	10.37	3.93		13.9	123.9	8.91	3.89		7.82	
D 1135	15.0	106.4	7.09			11.4	68.2	5.99				
U. D. 65	12.4	99.2	8.00	0.59		11.4	79.4	6.97	0.96		1.55	
D 1135	11.8	91.6	7.74			10.8	65.2	6.04				
U. D. 67	17.6	111.6	6.26		1.61	12.4	75.1	6.05		1.00		2.61
D 1135	11.4	91.9	8.01			10.7	86.3	8.06				
U. D. 70	14.7	103.9	7.05		0.66	11.1	105.7	9.52	2.71		2.05	
D 1135	11.9	88.2	7.42			10.9	60.7	5.57				
U. D. 79	14.5	102.2	7.02		0.10	10.9	107.5	9.86	4.42		4.32	
D 1135	11.7	79.9	6.83			11.7	62.3	5.32				
U. D. 100	13.3	104.0	7.79	1.16		13.1	118.5	9.05	4.35		5.51	
D 1135	11.6	74.8	6.44			11.0	44.8	4.08				
D 1135	11.5	78.9	6.83			12.7	66.9	5.27				
U. D. 104	10.4	107.5	10.33	3.46		12.2	85.4	7.00	1.90		5.36	
D 1135	10.6	72.9	6.88			11.4	56.2	4.93				
U. D. 106	13.3	76.8	5.77		0.26	13.8	79.1	5.74	0.64		0.36	
D 1135	14.2	73.6	5.88			12.2	52.1	4.27				
U. D. 110	12.5	84.4	6.75	0.81		10.9	92.4	8.48	4.04		4.85	
D 1135	12.8	85.3	6.71			11.3	52.2	4.62				
P-2	16.3	133.7	8.19	1.23		13.2	94.8	7.18	1.03		2.26	
D 1135	13.8	98.6	7.21			10.7	82.2	7.68				
U. B. 1	17.7	92.6	5.24		2.79	20.8	67.7	3.38		3.50		6.29
D 1135	10.3	91.6	8.86			10.4	63.3	6.09				
H. U. H. 3	10.3	71.3	6.92		0.75	10.1	86.3	8.54	3.00		2.25	
D 1135	10.2	66.2	6.48			12.7	63.2	4.98				
Uba	12.0	41.3	3.43		1.95	10.0	84.8	8.48	4.39	2.44		
D 1135	9.3	40.0	4.29			9.2	29.5	3.20				

Variety	1927 Crop—19 Months Old Plant Cane Q. R.	Tons per Acre Cane	Tons per Acre Sugar	Gain T. S. P. A.	Loss T. S. P. A.	1928 Crop—18 Months Old First Ratoons Q. R.	Tons per Acre Cane	Tons per Acre Sugar	Gain T. S. P. A.	Loss T. S. P. A.	Plant and First Ratoons Gain T. S. P. A.	Plant and First Ratoons Loss T. S. P. A.
D 1135	13.7	71.0	5.19			14.8	59.8	4.04				
U. D. 28	25.3	99.3	3.92		2.46	16.8	110.9	6.60	2.03			0.43
D 1135	10.3	78.1	7.58			12.2	62.3	5.10				
U. D. 37	12.7	112.7	8.87	2.16		12.6	111.5	8.85	3.63		5.79	
D 1135	12.3	71.9	5.84			12.1	64.5	5.32				
U. D. 41	33.7	75.1	2.23		5.32	23.1	68.3	2.95		2.86		8.18
D 1135	10.5	97.3	9.26			10.3	65.0	6.31				
U. D. 47	23.1	92.6	4.01		4.89	12.9	84.7	6.56	1.18			3.71
D 1135	10.2	86.9	8.54			12.0	53.6	4.46				
U. D. 50	9.3	66.2	7.10		0.19	9.6	53.7	5.59		0.09		0.10
D 1135	10.6	64.0	6.04			9.3	64.3	6.90				
U. D. 60	14.4	82.0	5.68	0.13		10.4	88.1	8.47	3.17		3.30	
D 1135	8.7	43.9	5.06			9.9	36.6	3.70				
Uba	12.9	43.9	3.40		1.15	8.6	68.6	7.98	3.62		2.47	
D 1135	9.9	40.0	4.04			10.0	50.3	5.03				
D 1135	14.7	86.1	5.86			14.2	45.2	3.18				
U. D. 11	16.7	85.5	5.00		1.25	22.7	53.3	2.35		1.47		2.72
D 1135	10.0	66.4	6.64			10.9	48.6	4.46				
U. D. 71	18.7	66.4	3.55		3.82	16.5	43.2	2.62		1.96		5.78
D 1135	9.7	78.6	8.10			9.8	46.1	4.70				
U. D. 75	10.2	94.9	9.30	1.45		13.8	76.7	5.56	1.14		2.59	
D 1135	9.97	75.8	7.60			10.0	41.5	4.15				
Uba	11.1	90.1	8.14	1.30		11.3	115.1	10.18	5.53		6.83	
D 1135	11.7	71.3	6.09			11.4	58.9	5.16				
U. D. 78	13.6	86.9	6.37	0.37		12.4	65.7	5.30		0.57		0.20
D 1135	12.2	86.9	7.11			12.1	79.7	6.59				
U. D. 85	17.9	88.5	6.14		1.03	18.3	88.4	4.83		1.22		2.25
D 1135	12.5	90.1	7.18			10.6	55.1	5.20				
U. D. 88	11.8	110.0	7.84	2.13		12.4	66.4	5.35	0.24		2.37	
D 1135	14.4	61.2	4.25			10.0	50.3	5.03				

Variety	1927 Crop—19 Months Old Plant Cane Q. R.	Tons per Acre Cane	Tons per Acre Sugar	Gain T. S. P. A.	Loss T. S. P. A.	1928 Crop—18 Months Old First Ratoons Q. R.	Tons per Acre Cane	Tons per Acre Sugar	Gain T. S. P. A.	Loss T. S. P. A.	Plant and First Ratoons Gain T. S. P. A.	Plant and First Ratoons Loss T. S. P. A.
D 1135	10.5	61.3	4.28			13.8	50.2	3.64				
U. D. 92	13.0	70.2	5.40		0.04	11.3	98.1	8.68	5.01		4.97	
D 1135	10.4	68.6	6.60			11.6	43.0	3.70				
U. D. 94	11.4	62.6	5.58		2.27	13.2	57.1	4.32		0.30		2.57
D 1135	8.8	80.2	9.11			10.7	59.2	5.53				
U. H. 1	10.0	77.5	7.75		1.60	10.2	68.9	6.75	1.52			3.12
D 1135	10.1	97.3	9.60			11.2	59.4	4.94				
U. B. 3	12.0	74.8	6.23		1.97	12.9	69.3	5.37	0.61			1.36
D 1135	11.2	76.8	6.81			12.9	59.2	4.59				
U. H. 3	27.5	147.3	5.36		0.84	16.2	104.6	6.45	2.26		1.41	
D 1135	13.5	75.8	5.59			14.3	54.3	3.80				
U. D. 34	12.0	82.5	6.82	0.37		12.7	74.3	5.85	0.28		0.65	
D 1135	11.2	82.0	7.31			11.5	84.4	7.34				
U. D. 6	14.1	80.0	5.68		1.21	12.9	80.1	6.21	0.13			0.08
D 1135	13.4	86.9	6.48			11.6	56.1	4.83				
D 1135	11.6	98.0	8.44			12.1	82.2	6.88				
U. D. 75	11.0	133.8	12.17	5.36		13.0	108.7	8.36	2.90		8.26	
D 1135	13.7	71.0	5.19			14.8	59.8	4.04				

E. E. Naquin has the following to say concerning the Uba hybrids in the above test:

The merits of seedlings as commercial canes were pointed out in the writings of the previous crop, harvested in February, 1927. Their values commercially remain about the same, with a few exceptions.

H. U. H. 6, U. D. 14, 21, 26, 28, 35, 47, 60, 70 and 79, which are generally good yielders, but poor in the quality of their juices, show much better juices in the ratoon than in the previous plant crop. This accounts for their increase in sugar over the plant crop, the cane yield being about the same as in previous crops. Of the above seedlings H. U. H. 6, U. D. 14 and U. D. 28 showed the poorest juices.

Among the most promising seedlings the following give in the ratoon crop an actual increase in sugar per acre as compared with the plant crop: U. D. 9, 39, 70, 79, 92, 100, 110 and Uba. They all show a slight increase in tonnage, but a considerable improvement in the quality of the juices.

U. D. 1 and 37 have about an even break in sugar per acre as compared with the previous crop, while U. H. 4, U. D. 7, 75, 104 and P-2 show a decrease in yield of cane per acre with variable quality ratio. U. D. 58 shows an increase in cane yield, but an inferior quality ratio as compared with the plant crop.

In comparing the yields of the two crops with our standard cane, D 1135, we note a much larger gain in yield of sugar per acre in the first ratoons as compared with the plant crop. This is largely due to the great decrease in the yield of our standard cane D 1135. The average yield of sugar per acre of D 1135 was 6.89 for the 1927 crop and 5.06 tons for the 1928 crop. This decrease was directly due to the crowding out of the D 1135 by the rapid and rank growth of the Uba seedlings.

It is interesting to note that Uba shows a better quality of juices than any of its offspring.

In connection with the above test it may not be out of place to call attention to the performance of some of the Uba hybrids on other plantations.

U. D. 1 is too well known to require comment. We are all familiar with its fine vigor and ratooning power. Except for its susceptibility to eye spot and its tendency toward poor juices, it would be a super cane.

U. D. 4 is attracting interest at Kilauea. It has shown itself in several tests to be able to outyield its sisters and the older P. O. J.'s, under certain Kilauea conditions.

U. D. 50 is showing up well at Hutchinson plantation. It has the largest stick of any of this series, but has usually fallen down in ratooning. At Hutchinson, however, it seems to have found conditions to its liking and is ratooning quite satisfactorily.

U. D. 62 is another large-sticked cane. It promises to be useful in H 109 chlorosis areas. Ewa has planted a number of its coral chlorosis spots to U. D. 62, with indications of good success.

Under mauka conditions generally, both on Hawaii and Kauai, U. D. 9, 58, 75, 100 and 110 are the leaders. The latter cane grows better at high altitudes than any other cane we have seen thus far.

The fact that the canes named have come from a handful of only 110 seedlings points to Uba blood as one of the most promising for hard conditions. Every effort is being made to produce Uba hybrids and quarterbreeds in large numbers.

About 800 Uba hybrids were produced last year, mostly from Uba × H 456. They are a very promising lot, with larger sticks than the Uba × D 1135 seedlings, with no symptoms of node gall thus far and, on the whole, with good juices.

Uba germinations for this season are still under way, but indications are that between 600 and 1,000 will be obtained from various males.

Natal Uba seems especially promising as breeding material. It tassels earlier than Hawaiian Uba, at a time when pollen from other canes is still obtainable. It also seems to produce seedlings somewhat more freely, and the seedlings tend to be less grassy than those from Hawaiian Uba.

A. J. M.

Variety Tests at Olaa Sugar Company

By Raymond K. Conant

Introduction

Some of the more outstanding cane varieties at Olaa, which showed promise of being competitors of D 1135, were selected in 1927 from a number of seedlings on the plantation and planted in fair variety tests with D 1135. One test was planted in an upper field and another in a middle belt field, where D 1135 is the standard cane.

The varieties selected for these tests were not considered suitable to lower land conditions where Yellow Caledonia is the standard. In view of this and the fact that no other seedlings planted on these lower areas showed promise, the tests were confined to the above mentioned areas.

The canes selected for these tests were K 107, U. D. 1, P. O. J. 979, K 202 and P. O. J. 36.

Plan of the Experiments

Olaa Variety Experiment 27-6 was located in Field J-1, Section D-1, elevation about 500 feet. The layout consisted of sixty-four plots, twenty-three of which were 1/40 acre in size, and forty-one of which were 1/20 acre in size. Each plot consisted of six straight lines, each line being 4.5 feet in width. The length of the lines was 40.3 feet for the 1/40 acre plots and 80.6 feet for the 1/20 acre plots. Every plot of each variety had an adjoining check plot of D 1135, so that we may consider the experiment in five separate parts.

Seed of the same age and condition was used for all canes.

Mudpress was applied to all plots at the rate of 12 tons per acre with the seed. Commercial fertilizer was applied uniformly to all plots in four applications so as to give 200 pounds nitrogen per acre, 20 pounds P_2O_5 per acre, and 200 pounds K_2O per acre. Cultivation was uniform to all plots.

Experiment 27-7 was located in Field 4-5, Section E, elevation about 1,700 feet. The layout of the experiment consisted of seventy plots. All plots were 1/20 acre in size, consisting of six straight lines. Each line was 4 feet in width and 90.75 feet in length. Again every plot of each variety had an adjoining check plot of D 1135, making five parts to the experiment.

The seed, fertilization and cultivation was uniform to all plots. In this experiment 500 pounds of bone meal was applied with the seed. Subsequent fertilization was the same as in Experiment 27-6.

Harvesting Procedure

In both experiments all six lines of each plot were cut and bundled. Every bundle in each plot was weighed. The trash deduction was obtained by taking trash weights on two bundles in each plot, the fifth bundle from either end of the two center lines being scaled for this purpose.

One bundle from each plot was taken for juice analyses. The bundle consisted of ten stalks taken at random through the plot. Each bundle was ground separately and 300 c.c. of juice from similar plots were mixed to make a composite sample and the analyses were made on the composite sample.

Harvesting Results

Olaa Sugar Company, Experiment 27-6, 1929 Crop. Field J-1, Section D-1, Elevation 500 feet. Variety Experiment.

Object: To compare K 107, U. D. 1, P. O. J. 979, K 202 and P. O. J. 36 with D 1135.

Layout: 64 plots, 1-41 inclusive, 1/20 acre each, consisting of 6 straight lines. Each line 80.6 feet by 4.5 feet. Plots 42-64 inclusive 1/40 acre each, consisting of 6 straight lines. Each line being 40.3 feet by 4.5 feet.

Plant Cane: Planted March, 1927.

Area: 2.625 acres.

Age at harvest: 23 months.

Harvested: February, 1929.

Results:

Plots	No. of Plots	Part	Mudpress With Seed	Fertilization in Lbs. per Acre N	P_2O_5	K_2O	Juice Analyses Brix	Poln.	Pur.	Per Cent P_2O_5	Per Cent K_2O	Q. R.	Yields T. C./A.	T. S./A.
K 107	7	I	12 T. p. a.	200	20	200	18.2	16.50	90.7	.024	.048	7.91	62.60	7.92
D 1135	7	I	"	200	20	200	18.1	16.80	92.8	.024	.057	7.68	63.19	8.22
U. D. 1	7	II	"	200	20	200	16.6	15.49	93.3	.017	.044	8.29	92.13	11.11
D 1135	7	II	"	200	20	200	16.9	15.39	91.1	.018	.035	8.40	46.01	5.47
P. O. J. 979	4	III	"	200	20	200	17.2	16.06	93.4	.016	.044	7.97	46.38	5.81
D 1135	4	III	"	200	20	200	17.4	15.91	91.4	.020	.061	8.16	56.92	6.97
K 202	6	IV	"	200	20	200	16.9	15.39	93.7	.025	.048	8.46	53.02	6.27
D 1135	7	IV	"	200	20	200	18.1	16.98	91.0	.018	.055	7.55	54.31	7.19
P. O. J. 36	7	V	"	200	20	200	17.2	16.00	93.0	.028	.053	8.05	101.65	12.62
D 1135	8	V	"	200	20	200	16.0	14.42	90.2	.026	.072	9.08	55.02	6.06

(See Fig. 1.)

LAYOUT OF OLAA VARIETY EXPERIMENT 27-6
WITH TONS CANE PER ACRE OF EACH PLOT

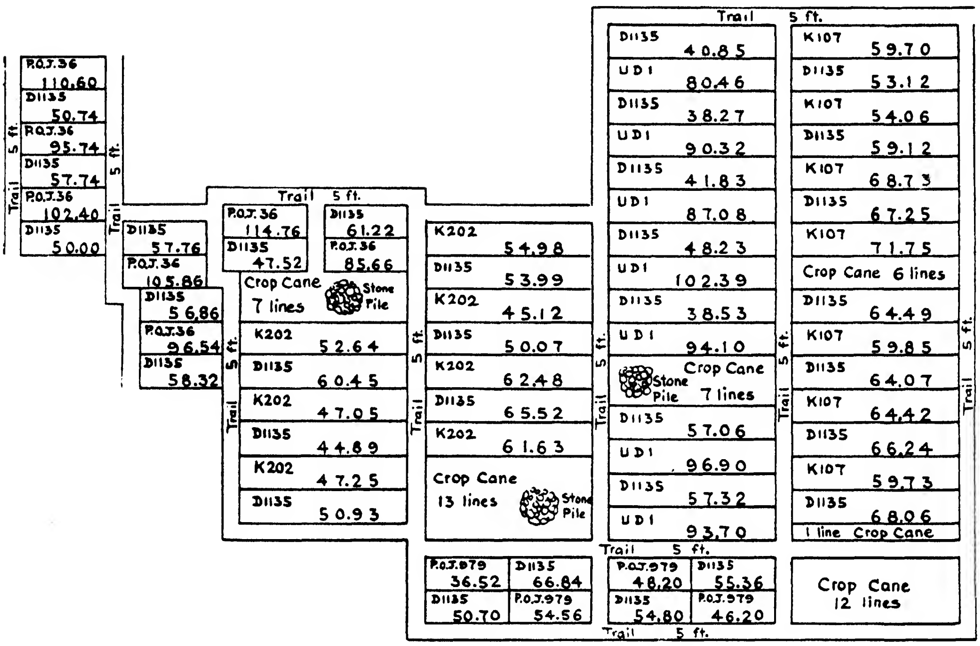


Fig. 1

The following table shows the T. C. P. A. and T. S. P. A. gain or loss figures of each cane in direct comparison with their respective checks of D 1135:

Variety	T. C. P. A.	T. S. P. A.	T. C. P. A. Gain or Loss	T. S. P. A. Gain or Loss	Per Cent T. C. P. A. Gain or Loss	Per Cent T. S. P. A. Gain or Loss
K 107	62.60	7.92	— .59	— .30	— .94%	— 3.8%
D 1135	63.19	8.22				
U. D. 1	92.13	11.11	+46.12	+5.64	+100 %	+103 %
D 1135	46.01	5.47				
P. O. J. 979	46.38	5.81	—10.54	—1.16	— 22 %	— 19.9%
D 1135	56.92	6.97				
K 202	53.02	6.27	— 1.29	— .92	— 2.4 %	— 14 %
D 1135	54.31	7.19				
P. O. J. 36	101.65	12.62	+46.63	+6.56	+ 84 %	+108 %
D 1135	55.02	6.06				

(See Fig. 2.)

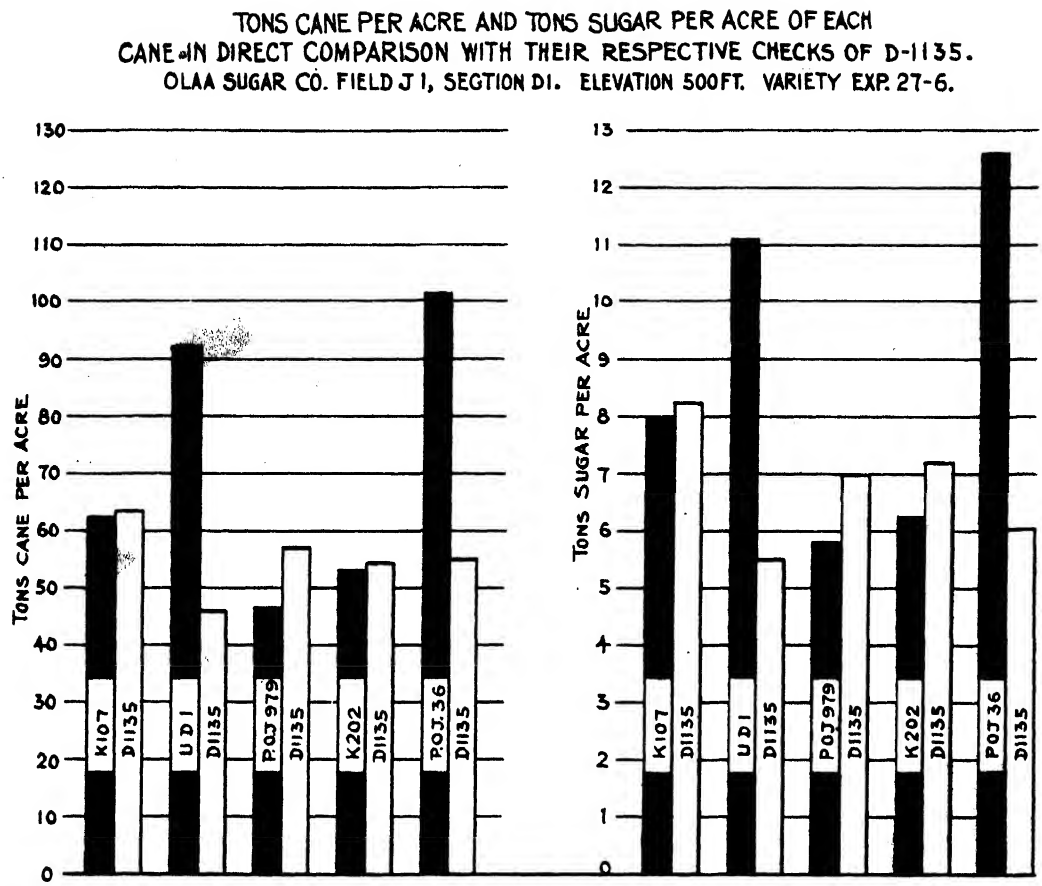


Fig. 2

Olaa Sugar Company, Experiment 27-7, 1929 Crop, Field 4-5, Section E, Elevation 1700 Feet. Variety Experiment.

Object: To compare P. O. J. 979, K 202, U. D. 1, K 107 and P. O. J. 36 with D 1135.

Layout: 70 plots, 1/20 acre each, consisting of 6 straight lines. Each line 4 feet by 90.75 feet.

Plant Cane: Planted April, 1927.

Area: 3.5 acres.

Age at Harvest: 22 months.

Harvested: February, 1929.

Results:

Plots	No. of Plots	Part	Bonemeal With Seed	Fertilization in Lbs. per Acre N	P_2O_5	K_2O	Juice Analyses Brix	Poln.	Pur.	Per Cent P_2O_5	Per Cent K_2O	Q. R.	Yields T. C./A.	T. S./A.
P. O. J. 979	6	I	500 lbs. p. a.	200	20	200	17.3	15.70	90.8	.009	.046	8.29	61.76	7.45
D 1135	7	I	"	200	20	200	16.8	15.10	89.9	.015	.065	8.65	59.12	6.84
K 202	7	II	"	200	20	200	16.2	14.62	90.2	.021	.051	8.95	48.75	5.45
D 1135	7	II	"	200	20	200	17.9	16.61	92.8	.015	.039	7.76	55.26	7.12
U. D. 1	7	III	"	200	20	200	16.6	15.47	93.2	.015	.048	8.30	72.22	8.70
D 1135	7	III	"	200	20	200	17.1	15.73	92.0	.015	.051	8.24	51.04	6.20
K 107	7	IV	"	200	20	200	18.4	16.75	91.0	.018	.046	7.76	67.30	8.67
D 1135	7	IV	"	200	20	200	16.8	15.23	90.7	.014	.068	8.58	68.61	7.99
P. O. J. 36	7	V	"	200	20	200	16.0	14.37	89.8	.016	.052	9.08	80.86	8.90
D 1135	7	V	"	200	20	200	15.5	13.62	87.9	.015	.065	9.74	63.32	6.50

(See Fig. 3.)

LAYOUT OF OLAA VARIETY EXPERIMENT 27-7 WITH TONS CANE PER ACRE OF EACH PLOT

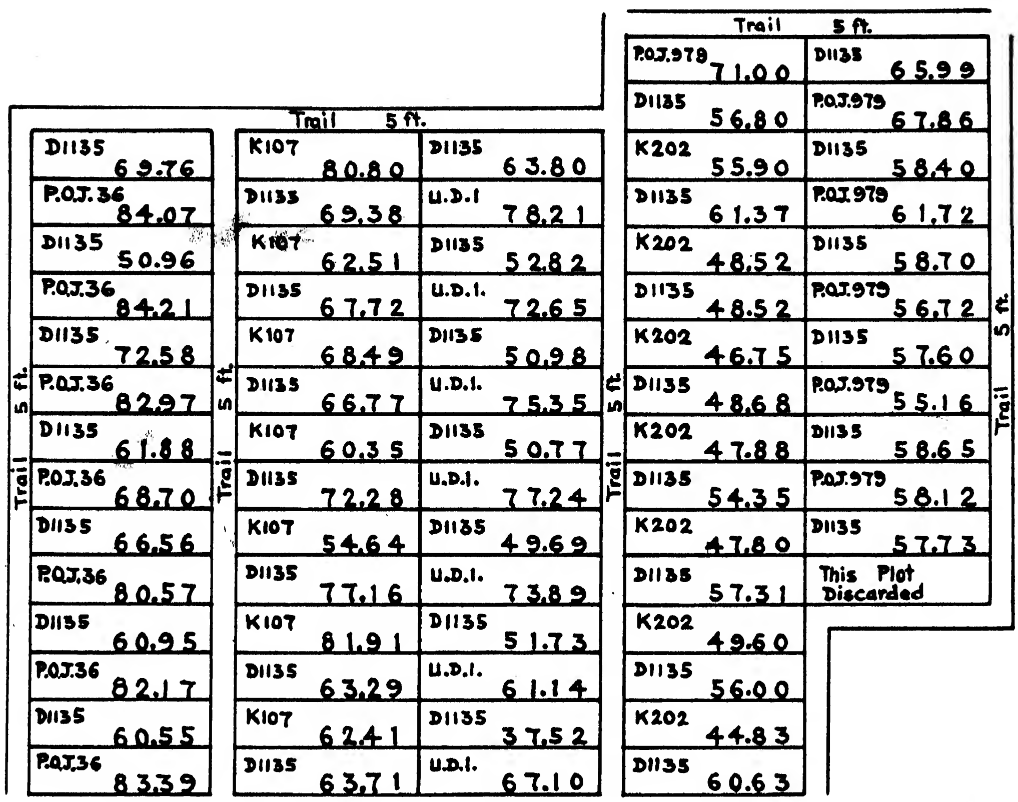


Fig. 3

T. C. P. A. and T. S. P. A. gain or loss figures of each cane in direct comparison with their respective checks of D 1135, for Experiment 27-7, follow:

Variety	T. C. P. A.	T. S. P. A.	T. C. P. A. Gain or Loss	T. S. P. A. Gain or Loss	Per Cent T. C. P. A. Gain or Loss	Per Cent T. S. P. A. Gain or Loss
P. O. J. 979	61.76	7.45	+ 2.64	+ .61	+ 4.4%	+ 9 %
D 1135	59.12	6.84				
K 202	48.75	5.45	— 6.51	—1.67	—13.4%	—30 %
D 1135	55.26	7.12				
U. D. 1	72.22	8.70	+21.18	+2.50	+41.5%	+40.4%
D 1135	51.04	6.20				
K 107	67.30	8.67	— 1.31	+ .68	— 1.9%	+ 8.5%
D 1135	68.61	7.99				
P. O. J. 36	80.86	8.90	+17.54	+2.40	+27.7%	+36.9%
D 1135	63.32	6.50				

(See Fig. 4.)

TONS CANE PER ACRE AND TONS SUGAR PER ACRE OF EACH CANE IN DIRECT COMPARISON WITH THEIR RESPECTIVE CHECKS OF D-1135. OLAA SUGAR CO. FIELD 4-5, SECTION E. ELEVATION 1700 FT. VARIETY EXP. 27-7.

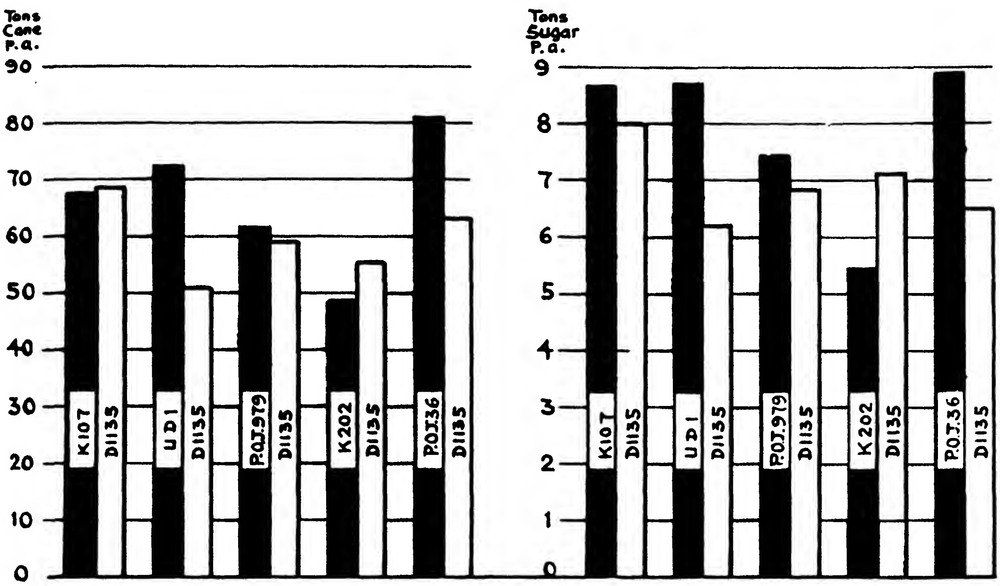


Fig. 4

Discussion of Results

In these two tests P. O. J. 36 and U. D. 1 were the outstanding canes. In Experiment 27-6, U. D. 1 gave an increase of 100 per cent in cane over D 1135, and 103 per cent in sugar. P. O. J. 36 gave an increase of 84 per cent in cane and 108 per cent in sugar over D 1135.

In Experiment 27-7, U. D. 1 gave an increase of 41.5 per cent in cane and 40.4 per cent in sugar. Here P. O. J. 36 gave an increase in cane of 27.7 per cent and 36.9 per cent in sugar over D 1135.

From these figures we might conclude that P. O. J. 36 is the better cane to plant in the middle belt and U. D. 1 a superior cane to extend on the upper lands of Olaa.

P. O. J. 36 appears highly resistant or immune to many cane diseases to which U. D. 1 is susceptible. Eye spot, mosaic, and node galls have appeared on U. D. 1 at Olaa, but not on P. O. J. 36. Eye spot on U. D. 1 has been the most prevalent and severe of the above diseases. Node galls have occurred occasionally on this cane, and mosaic frequently, but not severely enough to cause a noticeable effect on its growth.

Both of these canes have the ability to close in rapidly and suppress weed growth, germinate very well from seed, and have shown themselves to be good ratooners at Olaa, with U. D. 1 having the advantage in this respect. With a cropping system that involves both short and long crops, P. O. J. 36 has the advantage in juice qualities and the ability to hold over on the long crop. Both canes tassel heavily under certain conditions, but they rarely tassel in the middle belt and mauka areas of Olaa.

The points in favor of U. D. 1 as an upper land cane at Olaa are numerous, but one serious fault which would seem to automatically bar it from the list as a commercial cane, is the fact that it is susceptible to cane diseases which are known to cause losses in yields. Hence it is perhaps plausible to contend that P. O. J. 36 is more suitable for middle belt and mauka areas at Olaa than U. D. 1.

The other varieties tried out against D 1135 in these tests gave returns greatly inferior to P. O. J. 36 and U. D. 1. The K 107 plots were very irregular in yields, due perhaps to poor germination and mosaic disease. It is interesting to note that 25 per cent infection with mosaic disease was found on K 107 in Experiment 27-6. The juices here were poorer than that of D 1135. In Experiment 27-7 mosaic disease was not present on K 107 and its juices in this experiment were superior to D 1135.

K 107 is slow in starting at Olaa, and does not suppress weeds satisfactorily. Honohono climbs all over it when it gets older, making the harvesting and subsequent weeding very expensive. It is only a fair ratooner under Olaa conditions.

K 202 was poorer than D 1135 in both experiments. It had poor juices and was infected with mosaic disease. Weed growth was plentiful in the plots. The ratoons appear to be fair with this cane at Olaa.

P. O. J. 979 did not hold over in Experiment 27-6, much dead cane being present when the plots were harvested. It is too upright in growth habits, not having sufficient leaf spread for suppressing weeds. In both experiments dead tops were present on this cane when the plots were harvested. This is a typical indication of iron accumulation in the nodal joints. The iron test with a 10 per cent solution of potassium thiocyanate and dilute hydrochloric acid gave a positive reaction on these stalks with dead tops.

Summary

1. P. O. J. 36 gave a greater increase in sugar over D 1135 in the middle belt area, and U. D. 1 gave a greater increase in sugar over D 1135 in the upper land area.

2. Because of its susceptibility to dangerous cane diseases, U. D. 1 is perhaps automatically barred as a commercial cane even on the upper lands at Olaa Sugar Company.

3. P. O. J. 36 gave a substantial increase over D 1135 in both areas. Even though this increase over D 1135 in the upper land area was not as large as that shown by U. D. 1, yet because of its disease resistance P. O. J. 36 perhaps is the better cane for these Olaa areas.

4. The other varieties tried out against D 1135 in these experiments, viz., K 107, K 202, P. O. J. 979, gave inferior returns as compared to P. O. J. 36 and U. D. 1.

The writer is indebted to A. J. Watt, W. W. G. Moir, and the field and chemical staffs of Olaa Sugar Company for their kind advice and willing cooperation in these two endeavors.

Phosphoric Acid and Potash

WAIPIO EXPERIMENT V

By J. A. Verret

This experiment was started with the 1917 crop and has been continued ever since. The average yields of eight crops from 1917 to 1927 were slightly in favor of the nitrogen plots. The differences were too small to be significant and were likely due to the natural difficulties of conducting field experiments. These results are summarized herewith:

	Tons Cane per Acre				Q. R.				Tons Sugar per Acre			
Crop Year	N Plots	NP Plots	NK Plots	NPK Plots	N Plots	NP Plots	NK Plots	NPK Plots	N Plots	NP Plots	NK Plots	NPK Plots
1917	54.4	50.2	52.8	51.5	8.77	9.09	9.01	8.91	6.20	5.52	5.86	5.89
1918	55.3	54.5	53.8	53.7	9.54	9.10	9.34	9.18	5.80	5.99	5.75	5.85
1919	50.8	51.1	50.4	50.4	8.36	8.28	8.66	8.52	6.08	6.17	5.82	5.91
1921	85.0	84.2	78.8	82.7	9.15	9.15	9.15	9.15	9.29	9.20	8.61	9.00
1923	125.8	127.2	119.9	124.4	8.26	8.46	8.23	8.36	15.24	15.04	14.57	15.25
1924	73.7	74.0	74.1	74.5	Samples lost							
1926	110.2	113.1	105.7	110.2	8.36	9.12	8.50	8.64	13.19	12.40	12.44	12.75
1927	77.1	76.5	76.2	76.2	8.60	8.55	8.71	8.46	8.97	8.95	8.74	9.00
Avg.	79.0	78.8	76.4	77.9	8.72	8.82	8.80	8.73	9.25	9.04	8.83	9.09

The 1929 crop for the first time showed good gains for the plots getting complete fertilizer over the nitrogen plots. This is shown graphically in Fig. 1. Nitrogen plots Nos. 1 and 60 are corner, level ditch plots and are likely to be unduly favored. If these plots are omitted the results are rather consistently in favor of the complete fertilizer.

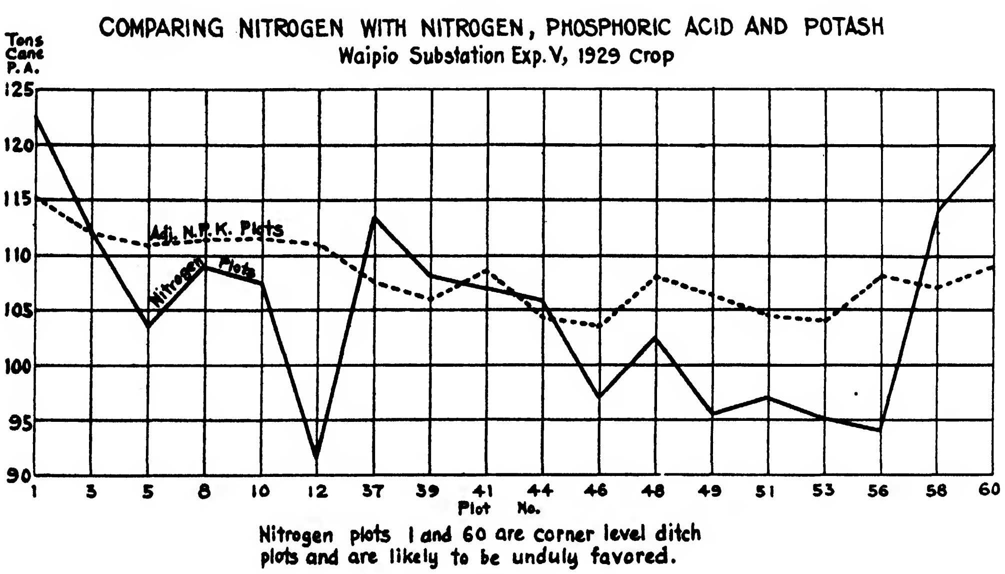


Fig. 1

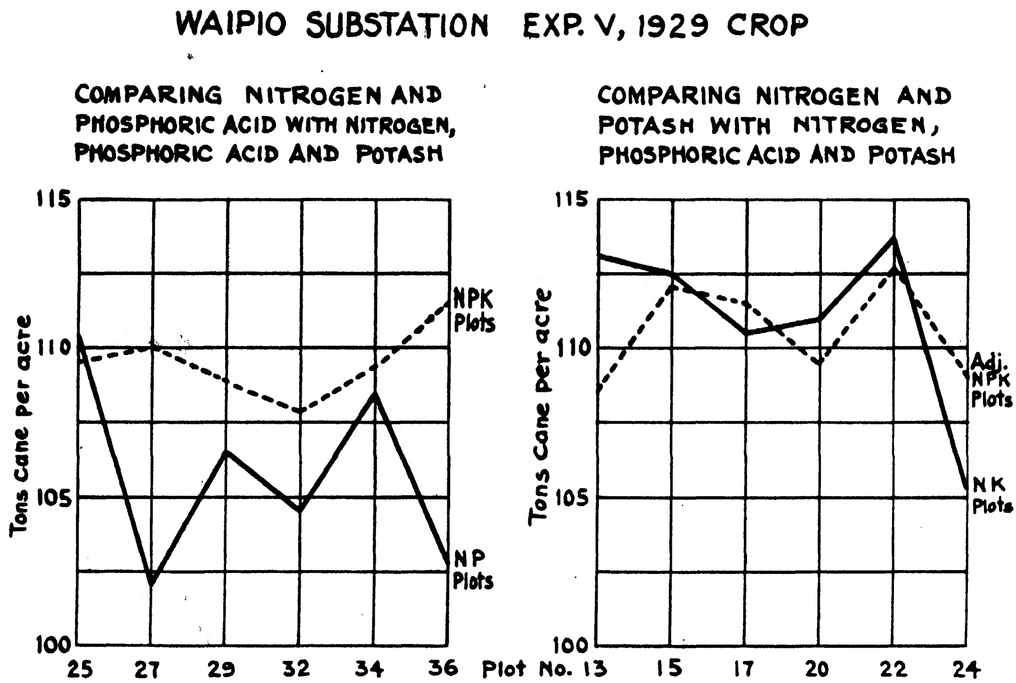


Fig. 2

In Fig. 2 we show by means of curves the comparative yields of plots getting nitrogen and phosphoric acid and nitrogen and potash with adjoining plots getting complete fertilizer.

These curves show significant gains of the complete fertilizer plots over adjoining plots getting only nitrogen and phosphoric acid. Such is not the case when we compare complete fertilizer plots with adjoining plots getting nitrogen and potash only. This indicates that the response is largely from potash.

This is exactly what one would expect from a study of the soil analysis as reported by Mr. Stewart, of the chemistry department:

Treatment	Soil Reaction pH	1 Per Cent Citric Acid Soluble Silica Per Cent	CaO Per Cent	K_2O Per Cent	P_2O_5 Per Cent	Total by Fusion K_2O Per Cent	P_2O_5 Per Cent
N Plots	6.9	0.16	0.17	0.023	0.0052	0.82	0.51
NP Plots	6.8	0.16	0.19	0.039	0.0100	0.50	0.48
NK Plots	6.8	0.16	0.15	0.045	0.0040	0.47	0.46
NPK Plots	7.0	0.17	0.21	0.028	0.0114	0.62	0.54

These analyses show a good supply of available P_2O_5 in all except the NK plots. These are just above the minimum supply and are likely soon to show more response to phosphate. The reverse is the case with the available potash where we find all plots to be low except the NK plots.

It is unfortunate that we did not have the analysis of these soils when the test was started. This is due to the fact that when this experiment was started the 1 per cent citric acid method had not yet been studied here and applied to our Island soils.

We feel that these results are extremely important in showing, as they do, how essential it is to carry on plant food tests in all areas where phosphoric acid and/or potash are omitted or applied in small quantities, in our fertilizer practices.

Here we have a case where for ten years phosphoric acid and potash were not needed and then we have distinct indications that the potash supply is getting low and needs to be built up.

PLANT FOOD TEST

H 109-4th RATOONS 20 MONTHS OLD

Waipio Substation Exp. V, 1929 Crop

Tons cane per acre for each plot

55 NPK 108.4	49 N 95.6	43 NPK 106.7	37 N 113.6	31 NPK 111.7	25 NP 110.4	19 NPK 104.7	13 NK 113.2	7 NPK 108.9	1 N 122.6
56 N 94.0	50 NPK 103.8	44 N 105.9	38 NPK 104.4	32 NP 104.5	26 NPK 111.8	20 NK 111.0	14 NPK 111.7	8 N 109.0	2 NPK 121.7
57 NPK 111.6	51 N 96.8	45 NPK 102.2	39 N 108.1	33 NPK 103.8	27 NP 102.2	21 NPK 109.5	15 NK 112.6	9 NPK 103.1	3 N 111.8
58 N 113.9	52 NPK 100.0	46 N 97.0	40 NPK 114.1	34 NP 108.4	28 NPK 114.5	22 NK 113.8	16 NPK 123.9	10 N 107.6	4 NPK 110.9
59 NPK 109.6	53 N 95.2	47 NPK 98.2	41 N 106.8	35 NPK 104.8	29 NP 106.4	23 NPK 102.9	17 NK 110.5	11 NPK 107.7	5 N 103.6
60 N 120.0	54 NPK 108.5	48 N 102.6	42 NPK 116.8	36 NP 102.8	30 NPK 113.3	24 NK 105.3	18 NPK 111.0	12 N 91.7	6 NPK 113.9

Field Road (bottom); Road / Field (right side)

Fig. 3

Unless these plant food tests are carried on from year to year we stand the chance of, some day, suffering serious losses.

The detailed layout and results from the 1929 crop are given as follows and shown in Fig. 3:

Object: Plant food test.
Location: Waipio Substation—Experiment V.
Crop: 1929 crop—4th ratoons—20 months old.
Layout: 60 plots approximately 1/30 acre, consisting of 8 lines with one guard on mauka and one on makai.

FERTILIZATION

	July, 1927			Sept., 1927-Feb., 1928			Totals	
Plots	A. S.	Sul. Pot.	Ad. Phos.	A. S.	A. S.	N	P_2O_5	K_2O
N	361	...	....	488	617	302	0	0
NP	361	...	1190	488	617	302	250	0
NK	361	500	....	488	617	302	0	250
NPK	361	500	1190	488	617	302	250	250

The guard rows were fertilized the same as N plots.

SUMMARY OF RESULTS

Plots	Treatment N	Treatment P_2O_5	Treatment K_2O	Yields per Acre Cane	Yields per Acre Q. R.	Yields per Acre Sugar
N	302	0	0	105.2	9.06	11.61
Adjoining NPK	302	250	250	108.8	8.85	12.29
NP	302	250	0	106.6	8.82	12.09
Adjoining NPK	302	250	250	109.5	8.85	12.32
NK	302	0	250	109.7	9.05	12.12
Adjoining NPK	302	250	250	109.5	8.85	12.32

PLOT YIELDS

Plots	Total Tons Cane	Area	T. C. P. A.	Q. R.	T. S. P. A.
1N	4.535	.0370	122.6		
3N	4.250	.0380	111.8		
5N	3.990	.0385	103.6		
8N	4.415	.0405	109.0		
10N	4.143	.0385	107.6		
12N	3.623	.0395	91.7		
37N	4.260	.0375	113.6		
39N	4.162	.0385	108.1		
41N	4.218	.0395	106.8		
44N	4.235	.0400	105.9		
46N	3.735	.0385	97.0		
48N	3.847	.0375	102.6		
49N	3.680	.0385	95.6		
51N	3.825	.0395	96.8		
53N	3.855	.0405	95.2		
56N	3.855	.0410	94.0		
58N	4.555	.0400	113.9		
60N	4.380	.0365	120.0		
Average	....	.....	105.2	9.06	11.61
13NK	4.302	.0380	113.2		
15NK	4.335	.0385	112.6		
17NK	4.255	.0395	110.5		
20NK	4.162	.0375	111.0		
22NK	4.210	.0370	113.8		
24NK	4.055	.0385	105.3		
Average	....	.....	109.7	9.05	12.12
2NPK	4.6875	.0385	121.7		
4	4.0475	.0365	110.9		
6	4.615	.0405	113.9		
7	4.190	.0385	108.9		
9	4.122	.0400	103.1		
11	4.303	.0400	107.7		
14	4.300	.0385	111.7		
16	4.710	.0380	123.9		
18	4.440	.0400	111.0		
19	4.392	.0375	104.7		
21	4.163	.0380	109.5		
23	4.115	.0400	102.9		
26	4.527	.0405	111.8		
28	4.353	.0380	114.5		

Plots	Total Tons Cane	Area	T. C. P. A.	Q. R.	T. S. P. A.
30	4.362	.0385	113.3		
31	4.188	.0375	111.7		
33	4.152	.0400	103.8		
35	4.298	.0410	104.8		
38	4.177	.0400	104.4		
40	4.335	.0380	114.1		
42	4.440	.0380	116.8		
43	4.000	.0375	106.7		
45	3.985	.0390	102.2		
47	4.027	.0410	98.2		
50	4.258	.0415	103.8		
52	4.000	.0400	100.0		
54	4.070	.0375	108.5		
55	4.120	.0380	108.4		
57	4.352	.0390	111.6		
59	4.548	.0415	109.6		
Average	....	.....	109.4	8.85	12.36
25NP	4.195	.0380	110.4		
27	4.190	.0410	102.2		
29	4.310	.0400	106.4		
32	4.232	.0405	104.5		
34	4.175	.0385	108.4		
36	4.010	.0395	102.8		
Average	....	.....	106.6	8.82	12.09

AVERAGE OF CARLOAD SAMPLES TAKEN AT O. S. CO. MILL

Plots	Brix	Poln.	Purity	Q. R.
N	17.5	14.85	84.95	9.06
NP	17.6	15.14	86.05	8.82
NK	17.2	14.81	85.51	9.05
NPK	17.5	14.99	85.50	8.85

Colloids and the Caking Quality of Raw Sugars

By A. L. Holven

From the refiner's standpoint, caking and stickiness are the most seriously objectionable physical characteristics of certain Hawaiian raw sugars.

Caked sugars materially raise the cost of refining by increasing the labor involved in unloading steamers, warehousing, conveying, and cutting into process. The importance of this subject has led to a considerable amount of investigative work for the purpose of determining and eliminating the principal factors responsible for the caking of raw sugars. The fact that some raw sugars cake more readily than others led to the suggestion that the tendency of a sugar to become sticky and caked might be dependent on its colloid content, and in order

to settle this point W. R. McAllep, sugar technologist, Experiment Station, H. S. P. A., suggested that the question be investigated.

The investigation summarized in this report was therefore undertaken by the laboratory of the California and Hawaiian Sugar Refining Corporation, in order to study the possibility of a correlation between the colloid content and caking quality of raw sugars.

For the purposes of this study, a number of samples of raw sugars were simultaneously exposed to carefully controlled conditions of temperature and humidity in a constant humidity room in order to determine their comparative tendencies toward caking under the same atmospheric conditions. Comparison of these results with the colloid contents of the respective sugars has indicated that the amount of colloids has apparently no influence on the caking quality of the raw sugars, and the present report is issued merely for the purpose of summarizing these results as a matter of record.

Selection of Samples

In order that samples having a comparatively wide range of caking qualities might be studied, the selection of the samples used in these tests was based upon the relative amounts of each mark received in a caked condition at this refinery. Full Island bags of each of the following marks of raw sugar were segregated for these special tests:

Mark	Plantation	Location	Agents
45	Waimea Sugar Mill Co.	Waimea, Kauai	American Factors, Ltd.
Cir. L	Laupahoehoe Sugar Co.	Papaaloa, Hawaii	Theo. H. Davies & Co., Ltd.
47	Pioneer Mill Co.	Lahaina, Maui	American Factors, Ltd.
14	Olaa Sugar Co.	Olaa, Hawaii	American Factors, Ltd.
1	Hawn. Com. & Sugar Co.	Puunene, Maui	Alexander & Baldwin, Ltd.
33	Pepeekeo Sugar Co.	Pepeekeo, Hawaii	C. Brewer & Co., Ltd.
49	Oahu Sugar Co.	Waipahu, Oahu	American Factors, Ltd.
32	Onomea Sugar Co.	Papaikou, Hawaii	C. Brewer & Co., Ltd.
Cir. D	Hamakua Mill Co.	Paauilo, Hawaii	Theo. H. Davies & Co., Ltd.
20	Ewa Plantation Co.	Ewa, Oahu	Castle & Cooke, Ltd.

Determination of Caking Qualities

These samples were placed in the constant humidity room and exposed to dehydrating conditions for a period of eleven days in order to accelerate their caking. Relative humidity was maintained at about 40 per cent, with a temperature of approximately 80° F. On the sixth day of exposure, the samples of Circle L and Circle D were caked, and within the ensuing three days the remaining eight samples caked.

Atmospheric conditions within the constant humidity room were then changed to 60 per cent relative humidity and an average temperature of 71° F. in order to produce conditions which would tend to resoften the caked sugars. These conditions were maintained for eight days and resulted in resoftening all except

Circle D and Circle L, which were finally softened by an additional exposure of three days to a relative humidity of about 68 per cent.

The relative caking and resoftening times of each of the above marks during this period of observation were substantially as follows:

CAKING QUALITIES OF VARIOUS MARKS

Sample	Period For Caking	Period For Resoftening
Circle D	6 Days	11 Days
Circle L	6½ "	10 "
45	7 "	6 "
32	7 "	7 "
14	7½ "	8 "
33	7½ "	7 "
47	8 "	7 "
1	8 "	6 "
20	8 "	6 "
49	9 "	5 "

While some raw sugars are naturally more resistant toward caking than others, it is obvious that under appropriate conditions of humidity and temperature practically any normal raw sugar will cake. It is of interest to note that, in general, the sugars which were the most readily caked were the most difficult to resoften, and vice versa.

Analyses of Samples

Deductions as to the relative amounts of colloids present in each of the above samples are based upon cataphoresis dye values, gum determinations, and surface tension depressions, as determined on each of the above samples. The following paragraphs briefly outline the significance of each of these determinations:

Cataphoresis Dye Values

Dye values were determined by cataphoresis titrations with the dye "Night Blue" and represent, in parts per 100,000, the amount of positively charged dye required to neutralize the negatively charged colloids in the raw sugar solution. The dye value is assumed to be approximately proportional to the amount of colloids. (For a more detailed consideration of this subject the reader is referred to the article entitled "Revised Directions for Operation of the Dye Test for Approximate Quantitative Determination of Colloidal Material in Sugar and Sugar Liquors," M. S. Badollet and H. S. Paine, *Planter and Sugar Manufacturer*, August 13, 1927.)

Gums

Gums, as used in this report, refer to the alcohol insoluble organic matter. Previous investigations have indicated that gums may be regarded as indices of the approximate amounts of colloidal matter in raw sugars.

Surface Tension Depressions

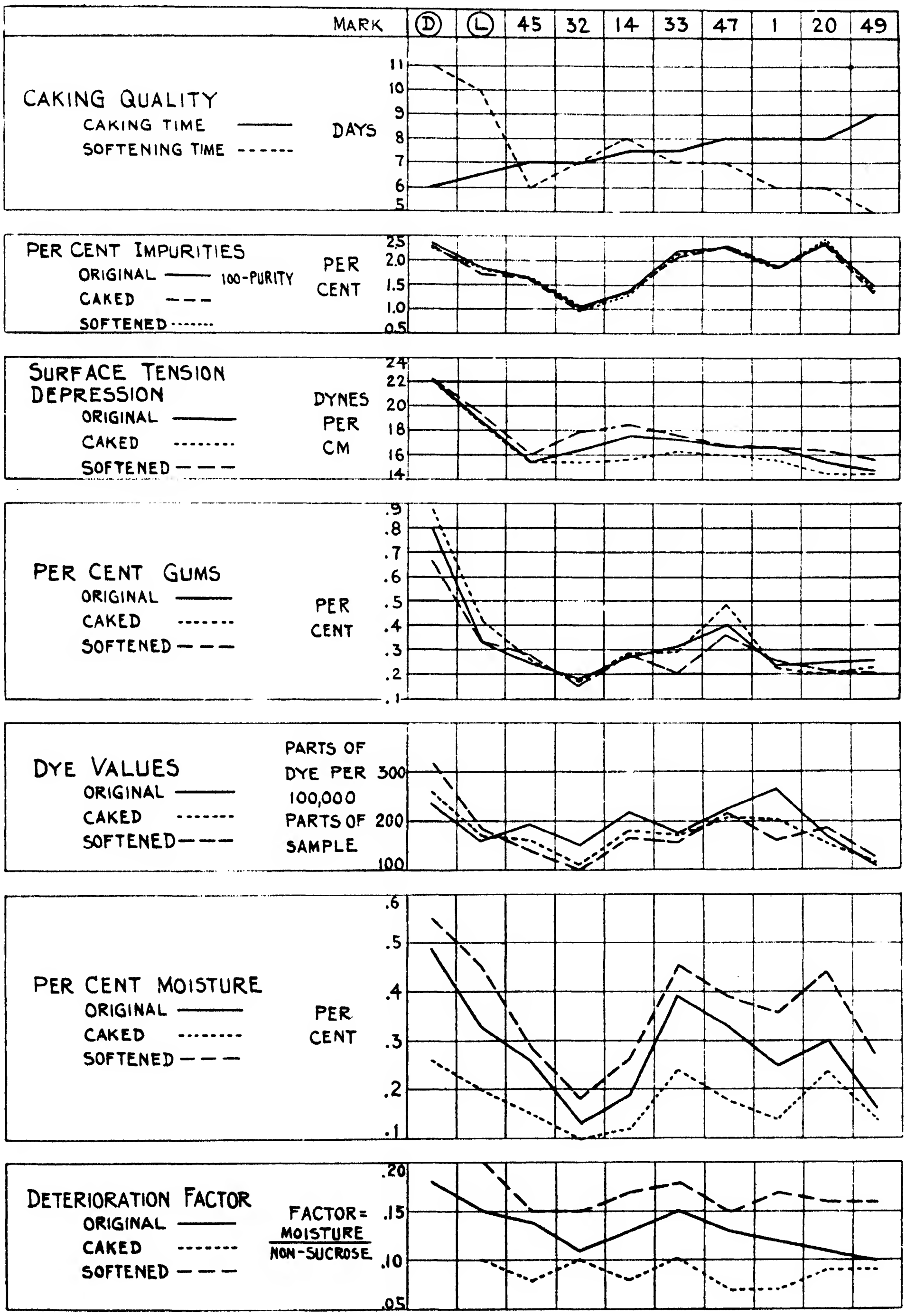
Surface tensions were determined by means of the du Noüy apparatus on 20 per cent solutions of the raw sugars. This value has been expressed as surface tension depression, which is the difference between the surface tension of the sample and the surface tension of a pure sucrose solution of the same concentration. Surface tension depressions increase with increasing colloid contents.

The above analyses, as well as polarizations and moisture determinations, were made on each of the above samples before the start of the tests, after all raws were caked, and after all raws were resoftened. The results of these tests are shown in the following tabulation:

ANALYSES OF RAW SUGAR SAMPLES

	Mark Cir. D	Mark Cir. L	Mark 45	Mark 32	Mark 14	Mark 33	Mark 47	Mark 1	Mark 20	Mark 49
Caking Time	6 Days	6½ Days	7 Days	7 Days	7½ Days	7½ Days	8 Days	8 Days	8 Days	9 Days
Resoftening Time	11 "	10 "	6 "	7 "	8 "	7 "	7 "	6 "	6 "	5 "
Original Free Running Sugars										
Direct Polinization	97.2	97.87	98.10	98.85	98.50	97.45	97.42	97.90	97.35	98.40
Moisture	0.49	0.33	0.26	0.13	0.19	0.39	0.33	0.25	0.30	0.16
Purity	97.68	98.19	98.36	98.98	98.69	97.83	97.74	98.15	97.64	98.56
Deterioration Factor	0.18	0.15	0.14	0.11	0.13	0.15	0.13	0.12	0.11	0.10
Surface Tension Depression	22.2	18.6	15.4	16.3	17.6	17.3	16.6	16.6	15.4	14.7
Per Cent Gums	0.80	0.34	0.25	0.18	0.27	0.31	0.40	0.24	0.25	0.26
Dye Value	235	160	190	150	219	175	223	263	170	110
Caked Sugars										
Direct Polinization	97.43	98.08	98.20	98.95	98.57	97.69	97.55	97.99	97.44	98.48
Moisture	0.26	0.20	0.15	0.10	0.12	0.24	0.18	0.14	0.24	0.14
Purity	97.68	98.28	98.35	99.05	98.69	97.93	97.73	98.13	97.67	98.62
Deterioration Factor	0.10	0.10	0.08	0.10	0.08	0.10	0.07	0.07	0.09	0.09
Surface Tension Depression	22.2	18.6	15.4	15.4	15.6	16.3	16.0	15.6	14.4	14.4
Per Cent Gums	0.88	0.43	0.26	0.17	0.28	0.29	0.48	0.23	0.20	0.23
Dye Value	260	170	160	110	180	173	210	200	155	115
Resoftened Sugars										
Direct Polinization	97.18	97.76	98.05	98.80	98.47	97.45	97.39	97.84	97.17	98.32
Moisture	0.55	0.45	0.29	0.18	0.26	0.45	0.39	0.36	0.44	0.27
Purity	97.72	98.20	98.34	98.98	98.73	97.89	97.77	98.19	97.60	98.59
Deterioration Factor	0.20	0.20	0.15	0.15	0.17	0.18	0.15	0.17	0.16	0.16
Surface Tension Depression	22.0	19.3	16.0	17.8	18.5	17.5	16.7	16.6	16.4	15.7
Per Cent Gums	0.67	0.34	0.27	0.15	0.28	0.20	0.36	0.25	0.22	0.21
Dye Value	320	185	140	100	165	155	215	160	185	125

COMPARISON OF
CAKING QUALITIES WITH OTHER CHARACTERISTICS OF RAW SUGARS



In the following tabulation, the sugars are arranged according to increasing colloid contents as indicated by the above determinations on the final samples, and these values are compared with their tendency toward caking.

COMPARISON BETWEEN COLLOID CONTENT AND CAKING QUALITY

Mark	Dye Value	Per Cent Gums	Surface Tension* Depression (Dynes per Centimeter)	Days Required to Cake	Days Required to Resoften
32	100	.15	17.8	7	7
49	125	.21	15.7	9	5
45	140	.27	16.0	7	6
33	155	.20	17.5	7½	7
1	160	.25	16.6	8	6
14	165	.28	18.5	7½	8
20	185	.22	16.4	8	6
Cir. L	185	.34	19.3	6½	10
47	215	.36	16.7	8	7
Cir. D	320	.67	22.0	6	11

(* Note: Surface tension depressions are usually regarded as indices of the relative amounts of emulsoid colloids, but in a number of instances these results are inconsistent with dye values and per cent gums. Therefore, the latter determinations are to be accepted as the more reliable indications.)

It is of interest to note that Mark Circle D, which had the highest colloid content caked the most readily, while Mark 49, which had next to the lowest colloid content was the most resistant toward caking. While these facts might indicate that caking was more or less dependent on colloid content, this supposition is not confirmed by the general trend of the other samples and it is believed, therefore, that the apparent relationship was merely coincidental.

As it had been noted that some of the Mark 49 received on February 23 was partially caked (i. e., sticky), it was believed that a comparison of the relative amounts of colloids in the sticky and normal Mark 49 sugars might yield further information on this problem. The results of comparative determinations on reserve samples of these sugars are as follows:

COMPARISON BETWEEN NORMAL AND STICKY

Mark 49—Received February 23

	Normal Raw	Sticky Raw
Dye Value	140	140
Per Cent Gums	.26	.19
Surface Tension Depression	19.2	16.0

While the dye values are identical, both the gums and surface tension determinations indicate that the sticky and caked raw actually contained a relatively smaller amount of colloids than the normal raw.

The results of these tests have indicated that there is no correlation between colloid content and caking quality.

As caking is logically being regarded as a cementing action resulting from crystallization in the molasses film, it is of interest to compare the caking quality of these sugars with their deterioration factors (relation between moisture content and total non-sucrose).

Mark	Caking Time	Resoftening Time	Purity	Moisture in Original Sample Per Cent	Deterioration Factor
Cir. D	6 Days	11 Days	97.7	0.49	0.18
Cir. L	6½ "	10 "	98.2	0.33	0.15
45	7 "	6 "	98.4	0.26	0.14
32	7 "	7 "	99.0	0.13	0.11
14	7½ "	8 "	98.7	0.19	0.13
33	7½ "	7 "	97.8	0.39	0.15
47	8 "	7 "	97.7	0.33	0.13
1	8 "	6 "	98.2	0.25	0.12
20	8 "	6 "	97.6	0.30	0.11
49	9 "	5 "	98.6	0.16	0.10

The above comparison indicates that there is no direct relationship between caking quality and either moisture or purity considered as separate factors. These results do indicate, however, that in general sugars with high deterioration factors are more readily caked than sugars with low deterioration factors. It is quite probable that the more rapid caking of sugars having high deterioration factors is due to the presence of a relatively greater quantity of syrup, which, upon evaporation, tends to cement the sugar crystals to a caked mass. Size of grain is another factor which may have more or less influence on the caking qualities of raw sugars.

The apparent relationship between caking quality and deterioration factor is in accord with a theory advanced by G. W. Aljian in the Quarterly Report for Raw Sugars Received at Crockett from the Hawaiian Islands—Second Quarter of 1926, March 27 to July 31, quoted as follows:

Caked and sticky raws received on steamers are classified in two groups—those received in the boiler hatches of the steamers and those received in all other hatches. Sticking or caking of the raws in the boiler hatches is a result of the high temperature of the atmosphere drying out the sugar during transportation. Raws from all plantations become sticky or caked when exposed to this condition. Caked and sticky sugars from non-boiler hatches must, however, be charged to the method of manufacturing or storing of the sugar prior to its delivery to the steamers.

The theory has been advanced that sticking and caking of raw sugar are dependent chiefly on the dryness of the syrup film surrounding the crystal. When this syrup is relatively dry, the sugar may be considered to become sticky because of the corresponding relatively high viscosity of the syrup. If this is the cause, it is reasonable to expect that the sugar may cake in a short time after storage when the voids between the crystals disappear through compression.

On the other hand, when the syrup surrounding the crystal is relatively wet through excessive or prolonged washing and poor drying, it is reasonable to expect that this syrup is relatively high in purity as a result of dissolving sucrose by the moisture enveloping the sugar crystal. It is also reasonable to expect that this syrup, being less hygroscopic because of its relatively small percentage of non-sugars, readily loses moisture when exposed to the atmosphere. When such drying takes place, the sugar is apt to cake due to a secondary crystallization that causes a cementing action to unite the crystals into a compact mass.

Conclusion

In briefly summarizing the results of this investigation, it is concluded that, apparently, colloids have no direct influence on the caking quality of raw sugars.

Caking quality does, however, appear to be more or less dependent on the relation between moisture and total non-sugars. As such, it is a partial substantiation of the theory that caking may be due to the cementing action caused by evaporation from a syrup film which, because of its high purity, is less hygroscopic than the syrup films of lower purity, which are associated with sugars more resistant toward caking.

These results have also confirmed the fact that under sufficiently dehydrating conditions, practically any raw sugar will cake, and the sugars which cake most readily are the most difficult to resoften, and vice versa.

In conclusion it may be stated that from present indications it is believed that the caking of raw sugars is a function of both the hygroscopic nature of the syrup and the relative humidity of the surrounding atmosphere.

Amounts of the Less Essential Plant Nutrients Present in the New Concentrated Fertilizers

By G. R. Stewart and F. R. Van Brocklin

During the past year Hansson* carried out an investigation of the less essential plant nutrients present in the materials at that time entering into our mixed fertilizers. In his discussion of this work, Hansson referred to the growing volume of evidence which is being obtained, regarding the needs of many crops for these less usual nutrients. The current reports appearing from a number of the American and European experiment stations emphasize the importance of the rarer nutrients for crop plants and orchard trees. The amounts of the less usual nutrient elements required by any plant are very small. At the same time we have little information as to the supply of copper, manganese, boron, zinc, fluorine, bromine, iodine, aluminum and arsenic furnished by the average agricultural soil. Hence it is of interest to know the amounts of the rarer nutrients supplied by the fertilizers which are put on the land.

The materials examined by Hansson included, nitrate of potash, nitrate of soda, muriate of potash, both of German and American origin, sulphate of potash, sulphate of ammonia, superphosphate, bone meal and dried blood.

At the present time a number of new concentrated materials are being employed to manufacture more concentrated mixed fertilizers. It, therefore, appeared to be desirable to make an examination of these new synthetic products in order to determine whether they supplied any of the less usual ingredients. The results

* Some Unusual Constituents Present in Common Fertilizers. *Hawaiian Planters' Record*, Vol. XXXII, pp. 342-346, 1928.

of this examination are given in the accompanying table. Before discussing the results of the analyses, a brief description of these newer fertilizers may be of interest.

Calcium Urea or "Calurea"

Calurea is a mixture of equal parts of calcium nitrate and urea. Shipments which have been received in Hawaii have contained 34.3 per cent of total nitrogen. This nitrogen was divided into 6.5 per cent nitrate nitrogen, 0.5 per cent ammonia nitrogen and 27.3 per cent amid nitrogen.

Nitrophoska I. G.

This material is a mixed fertilizer which contains a high percentage of nitrogen, phosphoric acid and potash. A number of different formulae of this fertilizer are being manufactured abroad. At the present time formula No. 3 is offered for sale in the United States. This consists of 15.6 per cent total nitrogen, 32 per cent phosphoric acid and 16 per cent of potash. Nitrophoska is being used principally as the basis for high-analysis mixed fertilizers by the addition of nitrogen, phosphates or potash salts, to suit the needs of special crops in different districts.

Leuna Saltpetre

This salt is a mixture of equal parts of ammonium sulphate and ammonium nitrate, which are combined while in solution and then crystallized out into a homogeneous compound. The nitrogen content of the leuna saltpetre is approximately 26 per cent, of which 19 per cent is ammonia nitrogen and 7 per cent nitrate nitrogen.

Nitrate of Lime

The new nitrate of lime, which is largely imported from Germany, is a white crystalline product to which approximately 4 per cent of ammonium nitrate has been added, to aid in crystallization and to increase the nitrogen content. The nitrogen content of this new product is about 15.5 per cent.

Treble Superphosphate

This is a high-grade phosphate product, which is made by first treating a low grade of phosphate rock with an excess of dilute sulphuric acid, until the greater portion of the phosphate originally contained in the rock is dissolved in the sulphuric acid. The mixture of sulphuric and phosphoric acids is then separated from the rock residue by filtration and is used to convert a high-grade rock phosphate into a superphosphate. Because the sulphuric acid employed for this final treatment of the phosphate rock already contains phosphoric acid, the resulting superphosphate contains more than double the usual content found in ordinary superphosphates. The shipments of double and treble superphosphate, commonly received in Hawaii, range in phosphate content from 45 to 52 per cent P_2O_5.

Ammonium Phosphate

Several formulae of ammonium phosphate are now sold on the American market. These materials are all compounds of synthetic ammonia and of phosphoric acid, which is generally prepared from the lower grades of phosphate rock. Two formulae of ammonium phosphate have been widely sold under the trade-name of "Ammophos". One grade of this product contains 16.54 per cent nitrogen and 20 per cent phosphoric acid. The other formula carries 10.7 per cent nitrogen and 48 per cent phosphoric acid.

Ammonium Nitrate

Ammonium nitrate contains approximately 34.5 to 35 per cent nitrogen. This nitrogen is present as equal amounts of ammonia and nitrate nitrogen. Ammonium nitrate has a considerable industrial use as well as its application as a fertilizer. There is now an appreciable tariff upon the foreign product, so that this salt will probably not find a large market as a fertilizer until it is made on a larger scale in the United States.

Urea

This product is the most concentrated nitrogenous fertilizer which has been produced up to this time. It contains 46 per cent of amid nitrogen, which is chemically classed as being equal to the organic nitrogen derived from slaughter house by-products. Urea has not been used to any great extent on a commercial scale, as it is a comparatively new fertilizer material.

Rare Constituents Found in the Fertilizers

In Table I, the amounts of manganese, copper, zinc, boron, iodine, bromine and fluorine found in the new products are listed on a percentage basis. In order that a comparison may be made of the results previously obtained by Hansson we have reprinted his analytical results upon the older fertilizer materials as Table II. The following comparisons may be made between the newer and older fertilizers.

Manganese

Hansson found traces of manganese in nitrate of potash and German muriate of potash and small but determinable amounts of manganese in nitrate of soda and bone meal. We now find that the newer forms of fertilizer contain larger amounts of manganese than were found in the older products. Those materials in which no manganese was found were ammonium nitrate, urea and calcium urea.

Copper

All the newer forms of fertilizer contain minute quantities of copper. The older materials containing copper were sulphate of ammonia, bone meal and dried blood.

Zinc

All the new concentrates carry small amounts of zinc. Of the older materials only sulphate of ammonia contained any zinc.

Boron

None of the new concentrates contained any traces of boron. In the older materials boron was found in small amounts in nitrate of potash, American muriate of potash, nitrate of soda and sulphate of potash.

Iodine

None of the new forms of fertilizer were found to contain iodine, either as free iodine or as the iodate. In the older products traces of free iodine were found to be present in nitrate of potash, muriate of potash, nitrate of soda and in superphosphate. Iodine combined as an iodate was present in nitrate of potash, American muriate of potash and in nitrate of soda.

Bromine

Bromine was found in only one of the newer materials, that is in nitrophoska. In the older materials, bromine was found in nitrate of potash and in both German and American muriate of potash.

Fluorine

Traces of fluorine were found in treble superphosphate and ammonium phosphate of the new products. Fluorine was found in the older materials in sulphate of ammonia and superphosphate.

Summary

To summarize the above pieces of work, it may be pointed out that the new concentrated materials examined at this time contain more manganese, copper and zinc than the older forms of fertilizer materials.

None of the new products supply any boron or iodine. Fluorine is present in traces in materials derived from several of the phosphate rocks and is found in approximately equal amounts in the older and newer forms of phosphates.

Work is now under way in this laboratory to determine which of these less usual nutrients are essential to the growth of the cane plant. The amounts of the rarer nutrients required for any crop so far investigated have been found to be exceedingly small. It must also be emphasized that an excess of these rarer plant nutrients is in most cases extremely toxic for plant growth. None of the fertilizer materials examined by Hansson or the writers appears to contain excessive amounts of the rarer ingredients. It would appear to be perfectly possible to obtain small amounts of the more important of the rare nutrients in mixed fertilizers, which are largely made from the new concentrated materials, if American muriate of potash is used as a source of potash. This potash salt carries a minute amount of boron, iodine and bromine, which are lacking in the new concentrated materials.

We have also work under way to try to determine the presence of the less usual elements in a number of our typical plantation soils. These current investigations will enable us to state how much importance should be given to the presence or absence of the rarer nutrients in estimating the probable value of a fertilizer.

TABLE I

ANALYTICAL RESULTS

Percentage of Some of the Unusual Constituents in the Concentrated Fertilizers

Fertilizer Material	Per Cent Manganese as MnO	Per Cent Copper as Cu	Per Cent Zinc as Zn	Per Cent Boron as $Na_2B_4O_7$	Per Cent Iodine as Iodide I	Per Cent Iodine as Iodate I	Per Cent Bromine as Bromide Br	Per Cent Bromine as Bromate Br	Per Cent Fluorine as Fluoride Fl
Calcium urea	None	0.0016	0.0024	None	None	None	None	None	None
Nitrophoska I G	0.0139	0.0074	0.0040	None	None	None	0.0144	None	None
Leuna saltpetre	0.0068	0.0029	0.0024	None	None	None	None	None	None
Nitrate of Lime	0.0114	0.0024	0.0024	None	None	None	None	None	None
Treble superphosphate	0.0123	0.0220	0.014	None	None	None	None	None	Trace
Ammonium phosphate (Anaconda)	0.0105	0.0340	0.032	None	None	None	None	None	Slight trace
Ammonium phosphate (16.4% N)	0.0121	0.0190	0.030	None	None	None	None	None	Trace
Ammonium phosphate (10.7% N)	0.0164	0.0091	0.014	None	None	None	None	None	Trace
Ammonium nitrate	None	0.0032	0.012	None	None	None	None	None	None
Urea	None	0.0024	0.020	None	None	None	None	None	None

TABLE II

ANALYTICAL RESULTS

Percentage of Some of the Unusual Constituents in the Common Fertilizer Materials

Fertilizer Material	Per Cent Manganese as MnO	Per Cent Copper as Cu	Per Cent Zinc as Zn	Per Cent Boron as $Na_2B_4O_7$	Per Cent Iodine as Iodide I	Per Cent Iodine as Iodate I	Per Cent Bromine as Bromide Br	Per Cent Bromine as Bromate Br	Per Cent Fluorine as Fluoride Fl
Nitrate of potash	Trace	None	None	0.404	Trace	.0240	0.0012	None	None
Muriate of potash (German)	Trace	None	None	Trace	Trace	None	0.094	None	None
Muriate of potash (American)	None	None	None	0.180	Trace	.0052	0.796	None	None
Nitrate of soda	.00046	None	None	0.095	Trace	.0104	Trace	None	None
Sulphate of ammonia	None	.00038	.035	Trace	None	None	None	None	0.145
Sulphate of potash	None	None	None	.0023	Trace	None	Trace	None	None
Superphosphate	None	None	None	None	None	None	None	None	Approx. 0.50
Bone meal	.0036	.00043	None	Trace	None	None	None	None	None
Dried blood	None	.00042	Trace	Trace	None	None	None	None	None

The Availability of Potash*

By W. T. McGeorge

In the progress and development of our knowledge of soil fertility, a great deal of time and effort has been expended in searching for definitely reliable guides to soil management. As one phase of this problem, some means of estimating plant food availability would admittedly be of infinite value. While soil chemists have devoted much effort to this phase of soil research, their extensive studies have thus far evolved only empirical methods of limited application. As a matter of fact some students of soil fertility question even a limited application.

It is recognized that a determination ot the total potassium in the soil, which can be very accurately made, serves only as an inventory of the reserve supply which may or may not, at some future time, become available to the plant. Only after the elements are dissolved in the soil solution do they become directly subject to assimilation. Furthermore, the amounts of plant food elements usually found in the soil solution represent only an extremely small percentage of that present in the soil. In addition to this, the concentration of the soil solution fluctuates greatly from day to day, as does also the ratio of the various elements present in solution and necessary in plant nutrition. This fluctuation is brought about by such agencies as rainfall, temperature, and draught of the crop, as well as a number of other factors. It is evident, that like the determination of total potassium in the soil, the analysis of the soil solution, or a water extract, is also of limited value.

It is believed that there are rather definitely defined periods in the growth of a crop, during which its plant food requirements will fluctuate greatly. Therefore, the availability or rapidity with which a necessary element will enter the soil solution is recognized as a controlling factor in crop performance. On this basis it may readily be seen why so much time has been devoted to methods of determining the available plant food in soils.

Recognizing the difficulty or even impossibility of attaching any sound, theoretical interpretation to a soil analysis, in which any reagent is employed as solvent, interpretations have been made largely empirical, as already stated. Such dilute acids as 1 per cent citric acid, N/5 nitric acid, as well as several others, have been extensively studied. On the basis that plants feed through the medium of a slight acidity within the feeding zone of the root tip, created by means of a secretion of carbon dioxide, the use of these weak acid solvents has, in the main, been an attempt to simulate root activity. The value of weak acid solvents for potassium, and their application to soil management on our island plantations, has been treated in Experiment Station, H. S. P. A., Bulletin 48 (4), so there is no need to go into further detail here. Suffice it to say that on the whole 1 per cent citric acid, as a measure of available potassium, interpretations being made on the basis

* Additional study and discussion on potassium availability is presented as a part of an accompanying article on Electrodialysis of Hawaiian Soils.

of data obtained from soils of known field performance, has found extensive and reliable application.

During the course of an intensive study of the low fertility of Kilauea soils, the availability of potash has received a commanding attention. The appearance of the plants in the field is indicative of potash starvation. There is a premature death of the lower leaves which begins with a "marginal firing", that is, a progressive drying from the leaf margin and leaf tip inwards and, in some cases, a deterioration or even premature death of the stalk. A rapid deterioration of cane following the period of tassel is characteristic of Kilauea-grown cane. Among the physiological properties of potash the greater resistance which it imparts to a crop against adverse climatic conditions is outstanding. Potash-deficient crops are usually the first to suffer in a bad season or in cold weather. In view of this well-known property of potash, coupled with our observations at Kilauea, it is not unreasonable to suppose that cane grown under the climatic conditions at Kilauea may have a higher potash requirement. Thus far our investigations have only touched upon the cane plant, soil studies having occupied our entire time. The above reference to the properties of potash is merely included as bearing upon the relation of potash to our problem and because our study is now being centered upon the plant. The soil studies have given much of value and are practically completed.

Field Experiments

It has generally been observed in field experiments at Kilauea that a variable response to potash will often appear during the early stages of growth only to completely, or almost completely, disappear at harvest. This may often be true where as much as 1,000 to 1,500 pounds potash (K_2O) per acre has been added, as was shown by Experiment 63 in Field 28.

Soil Survey

The soil survey of Kilauea plantation showed a good supply of potash, the total potash varying from 10,000 to 36,000 pounds K_2O per acre foot, but as measured by 1 per cent citric acid, the availability is very low. At our request, L. D. Larsen, manager of Kilauea plantation, kindly submitted a classification of all the

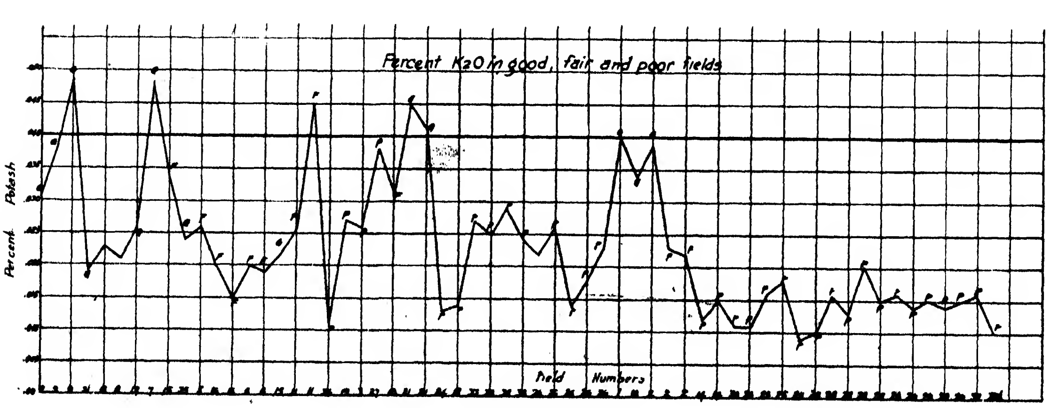


Fig. 1

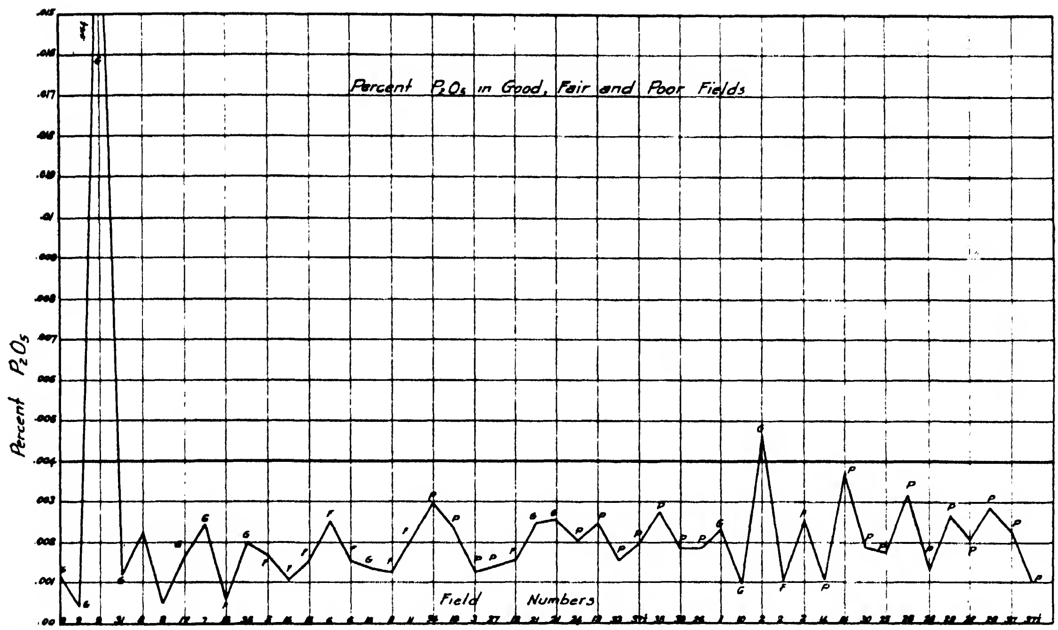


Fig. 2

plantation fields as good, fair or poor, according to yield. The availability of potash was then plotted and is shown graphically in Fig. 1. In this graph there is shown the per cent K_2O soluble in 1 per cent citric acid, with each point on the curve representing a field and designated as good, fair or poor. While there are a few exceptions, it will be noted that on the whole the good fields are characterized by higher potash availability, and the poor fields by low availability. As a matter of comparison, a similar graph is presented as Fig. 2, showing the relation between available phosphate and good, fair and poor classification. While it is evident that phosphate, too, is of very low availability, with the exception of two fields, all are uniformly low regardless of crop performance.

Fixation of Potash

From the soil analyses one would expect the poor fields to give a notable response to potash fertilization, since in other island districts such low potash soils respond readily. The failure of Kilauea soils to give more than a slight response where any response at all is obtained, brings up the question of the factors associated with the low availability. We were especially interested in learning if, after fertilization, the potash became fixed in a form no longer available to the plant and, if so, the nature of this absorption.

In character, the Kilauea soils, notably the mauka fields, are possessed of a highly dispersed yellow colloidal clay. The clay fraction of a soil is actively associated with the fixation of potash and is, for this reason, often referred to as the absorbing complex. While the identity of this absorbing complex has not been definitely established, it is apparently of the class of silicates known as zeolites, and this latter term, zeolite potash, will be used in referring to the absorbed potash throughout this paper. The bases, such as lime, magnesium, potassium and sodium,

which are held by the zeolite, are also often referred to as replaceable bases because of the fact that they are present in a very reactive form and, under certain conditions, the absorbed bases will be exchanged for other bases present in the soil solution or those added in fertilizer or irrigation water. In view of the great progress which has been made in the study of base fixation in soils since the publication of Bulletin 48, we have investigated the relation of the absorbed bases to potash availability in the Kilauea soils.

The presence of zeolites in soils was first recognized at least fifty years ago and to these compounds was attributed the fixing property of the soil. Their real function, their properties and the nature of their reactions, however, has only recently come to be understood and appreciated. One result of this has been a more definite understanding of the availability of potassium. This element is present in the soil solution only in small amounts, that is, as compared to calcium, magnesium and sodium. The potassium present in the soil solution, at any one time, is often considered as practically negligible. This has led to the suggestion that plants are largely dependent upon zeolite potassium for their nutrition. The question of the availability of zeolite potassium is, therefore, of paramount importance. Theoretically, potassium zeolite will hydrolyze and ionize in contact with water and thus supply soluble potassium to the plant, and Breazeale(2) has demonstrated that it does function in this manner. He has also shown that the reaction is enhanced by the presence of the soluble salt of another base. On the other hand, while some other soluble base is usually present in the soil solution this is not entirely necessary, as he has further demonstrated, because potassium zeolite will hydrolyze and ionize in water and yield, at equilibrium, a solution containing as much as 30 parts per million potassium.

Experimental

A number of good, fair, and poor fields at Kilauea were selected and samples of surface soil representing, the top foot, and subsoil, representing the second foot, were taken. In addition a sample from the Hilo Sugar Company, representing a soil that responds to potash, one from Ewa plantation which also responds to potash, and one each from Ewa and the Waipio substation representing soils which do not respond to potash. A description of these soils follows, the soils marked (a) being surface soils, and those marked (b) subsoils:

2a, 2b—greyish brown silty clay loam—a fair field.
5a, 5b—brownish yellow silty clay loam—a fair field.
7a, 7b—red to brown silty clay loam—a good field.
11a, 11b—red clay loam—a fair field.
12½a, 12½b—reddish yellow clay loam—poor field.
14a, 14b—yellowish brown silty clay loam—poor field.
16a, 16b—yellowish brown silt loam—good field.
21a, 21b—red silty clay loam—good field.
24a, 24b—yellow clay loam—poor field.
28a, 28b—brownish yellow silty clay loam—poor field.
33a, 33b—yellow clay loam—poor field.
37a, 37b—yellow brownish clay loam—poor field.

Most of the subsoils at Kilauea merge off to a pale reddish yellow color and somewhat heavier texture:

H—yellow gravelly loam—Hilo Sugar Company—responds to potash.
V—brown silty clay loam—Waipio substation—no response to potash.
VK—same as V, but from the potash plot of Experiment V.
11—clay soil—Ewa Plantation Company—responds to potash.
19B—red clay loam—Ewa Plantation Company—no response to potash.

2827—Experiment 63, Kilauea, Plot 3B, 1,500 lbs. K_2O per acre.
2828—Experiment 63, Kilauea, Plot 1X, no potash, near Plot 3B.
2829—Experiment 63, Kilauea, Plot 4X, no potash, adjacent to Plot 3B.
2830—Obs. test 5, Kilauea, Plot C1, no potash.
2831—Obs. test 5, Kilauea, Plot E3, 600 lbs. K_2O per acre.
2835—Experiment 68, Kilauea, Plot 16X, no potash.
2836—Experiment 68, Kilauea, Plot 15B, 1,000 lbs. K_2O per acre.

In Experiment 63 there was a slight response in plot 3B during the early stages, and a slight response at harvest in Experiment 68. The former is located in Field 28 and the latter in Field 25, both poor fields.

In these soils the bases calcium, magnesium, sodium and potassium were determined by extraction with strong hydrochloric acid, with 1 per cent citric acid, and the zeolite bases determined by replacement, using both normal ammonium chloride and tenth-normal barium chloride solutions. The zeolite hydrogen was determined by replacement with neutral normal solution of barium acetate, and the leachate titrated with N/10 barium hydrate, using the quinhydrone electrode. The replacement capacity was determined by leaching the soil with N/1 neutral ammonium acetate, washing free of ammonium with methyl alcohol, and determining the ammonium fixed by the soil. The results are given in Table I. In Table II the zeolite bases are given on a milligram equivalent basis.

Calcium: The citrate soluble calcium agrees fairly well with the zeolite calcium in the Kilauea soils, but less so in those from Hilo, Waipio and Ewa. In all cases the zeolite calcium is consistently higher, showing that 1 per cent citric acid will not, in a single extraction, dissolve all the zeolite calcium. There is noted a wide variation in the ratio of zeolite calcium to that soluble in strong hydrochloric acid and, in several cases, as high as 80-90 per cent of the hydrochloric acid soluble calcium is in the form of zeolite. In all cases the zeolite calcium is notably less in the subsoil than in the surface soil. There is no relation between the form of calcium present in the soil and the good, fair and poor classifications of fields; nor is there any relation between the citric soluble and zeolite potassium and the calcium. The same holds true when the calcium is figured on a milliequivalent basis, as shown in Table II.

Magnesium: With the exception of two fields, 28 and 33, the magnesium soluble in 1 per cent citric acid is greater than the zeolite magnesium. This does not hold true for the soils from Hilo and Ewa. The ratio of magnesium soluble in strong hydrochloric acid to zeolite magnesium is much lower than for calcium, but apparently this is of no important significance. Also, the magnesium determinations do not show any relation to the good, fair and poor classifications. While the zeolite magnesium is lower in the Kilauea soils than in those from

Waipio and Ewa, the Hilo soil, which gives a ready response to potassium, is, like the Kilauea soils, low in zeolite magnesium. Like calcium, the subsoils are all markedly lower in zeolite magnesium than are the surface soils.

Sodium: The sodium soluble in 1 per cent citric acid is a great deal less than that present as zeolite in the Kilauea and Hilo soils, while with the Ewa and Waipio soils there is rather close agreement. The ratio of sodium soluble in strong hydrochloric acid to that present as zeolite shows that this element is largely present in forms other than the zeolite and is, therefore, less available. Strange to say, there is a rather close agreement between the zeolite sodium in the soil and subsoil, which is in direct contrast to the calcium and magnesium. On the whole, the data give rather convincing evidence that the zeolite sodium is fixed more strongly in the Kilauea soils than in the more fertile soils such as the Ewa and Waipio types.

Hydrogen: The hydrogen combined with the zeolite to form soil acidity fluctuates over a wide range, probably due to the lime applications which have been made during years past. There is no consistency between soils and subsoils. In some cases the subsoils contain less zeolite hydrogen than the surface soils.

Potassium: Without a single exception the zeolite potassium, like the zeolite sodium, is greater than the citric soluble potassium. On the other hand, there is a close agreement between the zeolite potassium and that soluble in 1 per cent citric acid in the more fertile soils taken from Ewa, Waipio and Hilo districts. The potassium soluble in strong hydrochloric acid is largely present in forms other than the zeolite. While the zeolite potassium in the subsoil is in all cases less than the surface soil, like the sodium, it is not markedly less when compared with the divalent bases calcium and magnesium. In fact, it is very significant that a great difference exists in the divalent zeolite bases present in the soil and subsoil, while a close agreement exists in the monovalent bases present in the soil and subsoil. There is some variation in the zeolite potassium in Kilauea soils, but this is in no way related to the good, fair and poor classifications, and, on the whole, the Kilauea soils contain just as much zeolite potassium as the fertile soils from other districts. The soils from both the good Fields 7 and 21, are highest in citric soluble potassium, but otherwise they do not differ from the soils in other fields, especially in the amount of potassium present as zeolite. This low solubility of zeolite potassium in Kilauea soils is very significant and indicates that the solubility in 1 per cent citric acid is, for Hawaiian soils, a better indication of availability than the replaceable potassium determination.

Replacement capacity: The amount of base which a soil is capable of fixing is usually referred to as its replacement capacity. This property is being extensively determined in studying soil properties. As applied to the soils, which we have used in this study, the replacement capacity is not significant and, other than the lower capacity of the subsoils as compared to surface soils, it is of little interest to our problem.

The soils 2827-31 and 2835-6, shown at the bottom of Table I, were taken from three potash experiments at Kilauea, and they rêpresent check plots and potash plots from each experiment. All are from fields which are classified as poor, and the samples were taken in order to determine in what form the potash

had been fixed under field conditions. In Field 28, samples 2728-31, there was no response to heavy applications of potash. In Field 25, samples 2835-6, there was a small but consistent response. The data show that the zeolite potassium has been notably increased by the heavy fertilization, especially in 2827, where 1,500 pounds K_2O per acre was added with no response, and that it has been fixed as the zeolite which should be available to the plant. It appears, though, that like the zeolite potassium already present in the soil, it has been fixed in a form insoluble or difficultly soluble in 1 per cent citric acid. Furthermore, if the crop performance is any criterion, the fixation is beyond the limits of availability. In all three cases the hydrochloric acid soluble potassium is greater in the potash plots than the checks. While one cannot base conclusions on so few data, knowing the fluctuation in hydrochloric acid soluble potassium in soils and the difficulty in measuring small differences with this solvent, nevertheless the higher hydrochloric acid soluble potassium is significant and may indicate some fixation in a form even less available than the zeolite.

It is very evident from the preceding data and discussion that there is a great difference between the fixing power of the Kilauea soils and those from the more fertile districts, which are deficient and give response to potash fertilization or have been shown to be well supplied with available potassium. This applied only to the fixation of the monovalent bases potassium and sodium and not to the divalent bases calcium and magnesium. Aarnio(1) has recently noted a similar condition in the peat soils of Finland and says: "If peat is saturated with calcium and potassium ions, the potassium ions reduce the acidity more than the calcium ions. The absorbed potassium ions are attached *more firmly* than the calcium ions and their influence must therefore be *more 'tenacious' than that of the calcium ions.*" He interprets from his observations that it would be advantageous to add large amounts of potash with lime in correcting the acidity of peat soils. The zeolites with fixing and replacing properties are largely present in the finer soil particles, the colloidal clay fraction. May it not be true then that we have in the Kilauea clay a different type of zeolite? The first thing that strikes one on examining the Kilauea fields is the peculiar appearance of the clay or colloidal state. On drying, there is often the appearance of the shotty texture characteristic of many of the Hamakua soils on Hawaii. On wetting, although the clay fraction appears small, the clay will become highly dispersed and will clog up the pores of the soil. This is particularly true of the yellow clay soils, most of the better fields being of the red clay types. It is characteristic of the clay fraction of these yellow types from the poor fields to remain in suspension indefinitely when shaken with water in a glass cylinder, which is in direct contrast to the clay from the good fields which settles fairly readily under the same treatment.

It is generally recognized, and in fact it has been fairly well established, that the zeolites have a greater affinity for the divalent bases calcium and magnesium than for the monovalent bases sodium and potassium and, therefore, that they should be more strongly fixed. As measured by solution in 1 per cent citric acid, this holds true for the Ewa, Waipio and Hilo soils, but it is not true of the Kilauea soils. This also indicates a difference in the character and property of the Kilauea soil zeolite, which is probably associated with the poor availability of potassium

The fact that some soils have the property of fixing potassium in a form less available than the zeolite potassium has been observed by others. Quoting Truog(5), Wisconsin Experiment Station: "There appears to be some evidence that potassium, at least in part, goes over to a more insoluble form subsequent to its fixation as a replacement base in the colloidal complex. As a result of this the potassium becomes less available, and it would seem that the more desirable field practice would be to apply potash fertilizers in small, frequent applications rather than the reverse." A similar view is held by MacIntire(3) of the Tennessee Experiment Station, who says: "Some of our findings at Tennessee seem to substantiate the conclusion that whereas a part of the added potassium becomes leached a greater part becomes fixed by the soil. Some of the fixed potassium may be considered as fixed in a form which will yield fairly well to the pull exerted by the plant, whereas some of it may be considered as being rendered relatively insoluble. Using the observed parallel relative to the progressive decrease in solubility of calcium and magnesium which had been fixed from caustic and carbonate additions, it may be assumed that fixed potassium will continue to pass into forms more complex and less soluble."

As shown by the work of Breazeale(2), and this has been confirmed by other investigators, zeolite potassium should be just as available when subject to the feeding activities of plant roots as the soluble salts of potassium, such as the chloride or sulphate. On this basis we plan to study the availability of potassium, using the plant as the final indicator.

The availability of zeolite potassium is brought about through a hydrolysis and ionization of the zeolite complex by which process the potassium ion is brought into solution. As a means of studying this phenomenon in soils the dialysis of the soil zeolites has recently been extensively studied. By such a treatment the soil may be placed in a semipermeable bag of parchment or collodion placed in a vessel of distilled water and by intermittently removing the water from the vessel and replacing with fresh water the products of ionization and hydrolysis may be removed and quantitatively determined. The speed of dialysis may be greatly increased by applying an electric current to electrodes placed outside the dialysing membrane containing the colloid, a process known as electrodialysis. In order to see if electrodialysis would lend any information regarding the peculiar fixing property of Kilauea soils, a rather extensive study of this has been made, and is made the subject of an accompanying paper.

Summary

The relation between the bases soluble in 1 per cent citric acid, strong hydrochloric acid and that present in the form of zeolite has been determined in a representative set of soils from Kilauea plantation and compared with several other soil types of known potash availability.

The availability of potash in Kilauea soils, as measured by 1 per cent citric acid is very low.

Zeolite potassium in Kilauea soils compares very well with other island soils, but the solubility of zeolite potassium in citric acid is much lower in the former.

Potassium added in fertilizer is fixed by the soil zeolites in the Kilauea soils, just as in the Waipio soil, and appears to be just as reactive to replacement, but for some unknown reason the plant does not respond as it should.

There does not appear to be any relation between the amount and forms of other bases and the availability of potassium in this series of soils.

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SHOWING PER CENT BASES AND HYDROGEN IN SOILS, ON DRY BASIS

Soil No.	Cane Growth	Calcium (Ca) HCL Soluble	Calcium (Ca) Citric Soluble	Calcium (Ca) Zeolite	Potassium (K) HCL Soluble	Potassium (K) Citric Soluble	Potassium (K) Zeolite	Magnesium (Mg) HCL Soluble	Magnesium (Mg) Citric Soluble	Magnesium (Mg) Zeolite	Sodium (Na) HCL Soluble	Sodium (Na) Citric Soluble	Sodium (Na) Zeolite	Hydrogen as Zeolite (H)
2a	Fair	.35	.228	.280	.41	.014	.024	.23	.024	.017	.36	.017	.038	.004
2b		.25	.091	.122	.36	.013	.021	.31	.014	.004	.29	.018	.028	.008
5a	Fair	.23	.093	.105	.19	.013	.020	.24	.052	.030	.19	.015	.032	.006
5b		.23	.037	.038	.26	.013	.021	.18	.015	.012	.23	.014	.024	.0038
7a	Good	.32	.144	.198	.36	.019	.030	.34	.094	.070	.28	.020	.058	.0073
7b		.17	.059	.070	.30	.008	.034	.27	.022	.018	.26	.018	.036	.0033
11a	Fair	.26	.107	.144	.20	.015	.023	.29	.031	.017	.29	.017	.023	.0082
11b		.22	.049	.050	.25	.013	.019	.23	.014	.009	.39	.019	.037	.0048
12½a	Poor	.20	.070	.101	.30	.017	.030	.15	.034	.015	.27	.019	.029	.0098
12½b		.15	.039	.040	.29	.013	.022	.14	.015	.007	.27	.015	.023	.005
*14a	Poor	1.61	1.22	.400	.17	.017	.030	.29	.085	.013	.25	.021	.030	.....
14b		.49	.282	.213	.04	....	.015	.14	.022	.008	.23	....	.024	.0013
16a	Fair	.20	.089	.104	.37	.014	.021	.13	.045	.034	.21	.023	.052	.0102
16b		.15	.035	.040	.35	.013	.016	.30	.022	.007	.17	.022	.030	.0046
21a	Good	.33	.149	.213	.29	.022	.038	.28	.045	.040	.20	.018	.035	.0049
21b		.19	.078	.092	.54	.018	.019	.24	.030	.011	.23	.024	.042	.001
24a	Poor	.50	.345	.450	.32	.009	.015	.31	.037	.002	.16	.016	.032	.0024
24b		.13	.048	.053	.30	.005	....	.41	.008	.002	.20	.012	....	.0075
*28a	Poor	.53	.344	.364	.33	.006	.025	.12	.026	.029	.24	.014	.027	.....
28b		.19	.051	.055	.33	....	.019	.12	.005	.003	.26	.019	.033	.008
33a	Poor	.44	.183	.240	.25	.007	.043	.32	.049	.087	.23	.018	.044	.0078
33b		.14	.039	....	.20	.018	.022	.13	.015	.013	.22	.011	.039	.0106
*37a	Poor	1.75	1.140	.447	.25	.015	.032	.35	.083	.021	.25	.016	.034	.....
37b		.32	.215	.047	.16	.014	.019	.07	.015	.016	.29	.016	.043	.0047
H		.22	.026	.184	.16	.009	.011	.34	.002	.015	.37	.017	.036	.018
V		.32	.117	.209	.20	.035	.027	.24	.049	.067	.35	.036	.034	.....
VK		.35	.153	....	.19	.040	.049	.26	.065	.084	.33	.034	.040	.....
11		.39	.166	.208	.13	.014	.011	.35	.090	.124	.38	.064	.037	.....
19B		.50	.212	.364	.23	.033	.051	.64	.126	.169	.38	.052	.049	.....
*2827	Poor	2.02	1.27	.528	.28	.007	.050	...	....	.114	...	....	.025	.....
2828	Poor	.23	.19	.319	.17	.008	.012	...	....	.021	...	....	.029	.0048
2829	Poor	.28	.26	.378	.15	.013	.012	...	....	.020	...	....	.024	.....
*2830	Poor	.42	.39	.542	.16	.011	.012	...	....	.025	...	....	.022	.....
*2831	Poor	1.38	.92	.760	.21	.017	.021	...	....	.037	...	....	.028	.....
2835	Poor	.10	.05	.117	.28	.013	.012	...	....	.009	...	....	.021	.0088
2836	Poor	.10	.06	.121	.34	.015	.021	...	....	.015	...	....	.017	.0080

* Coral sand in soils.

TABLE II

Showing Zeolite Bases Calculated as Milligram Equivalents per 100 Gms. Soil

Soil No.	Calcium		Magnesium		Potassium		Sodium		Hydrogen		Total Replacement Capacity by Ammonium Acetate	
	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil	Soil	Subsoil
2	13.9	6.0	1.3	.3	.6	.5	1.6	1.2	4.0	8.2	17.2	14.3
5	5.2	1.9	2.0	1.2	.5	.5	1.3	1.0	6.0	3.8	14.0	7.1
7	9.8	3.4	5.7	1.4	.7	.8	2.5	1.5	7.3	3.3	21.3	9.2
11	7.1	2.4	1.4	.7	.5	.5	1.0	1.6	8.2	4.8	17.2	10.3
12½	5.0	1.9	1.2	.6	.7	.5	1.2	1.0	9.8	5.0	16.4	9.8
14*	19.0	10.6	1.0	.6	.7	.4	1.3	1.0	0.0	1.3	16.7	13.2
16	5.1	1.9	2.7	.6	.5	.4	2.2	1.3	10.2	4.6	18.1	11.2
21	10.6	4.5	3.2	.9	.9	.5	1.5	1.8	4.9	1.0	20.2	10.0
24	22.4	2.6	.1	.1	.4	..	1.3	...	2.4	7.5	21.1	11.2
28*	18.1	2.7	2.3	.2	.6	.5	1.1	1.4	0.0	8.0	16.9	13.6
33	11.9	...	7.1	1.0	1.1	.5	1.9	1.6	7.8	10.6	27.2	16.0
37*	22.3	2.3	1.7	1.3	.8	.5	1.4	1.8	0.0	4.7	18.4	11.7
H	9.1	...	1.2	...	.3	..	1.5	...	18.7	...	29.5	....
V	10.4	...	5.1	...	.3	..	1.4	...	...	...	16.8	....
VK	....	...	6.9	...	.9	..	1.7	...	...	...	18.4	....
11	10.3	...	10.1	...	.3	..	1.6	...	...	...	....	....
19B	18.1	...	13.8	...	1.3	..	2.1	...	...	...	31.6	....

* Coral sand in soils.

Soil Acidity: Replaceable Hydrogen and Replacement Capacity

By W. T. McGeorge

The use of lime in the fertilizer programme on the acid soils of our island plantations has been for a number of years a question for controversy. There is a feeling that lime should help to maintain a more permanent soil fertility and, on this basis, if no other, its use to some appears to be warranted. There are on record cases of injury from lime; others where no effect one way or another was noted; others in which response was obtained in the first crop following its application, and still others where no effect was noted until the third or even fourth crop after liming.

It is characteristic of our plantation areas that, proceeding mauka from lower elevations, there is a corresponding increase in the acidity of the soil. Likewise there is a corresponding decrease in sugar yields. One exception to the variation in soil reaction is of interest and significance. In the Kau district on the island of Hawaii, where cane is grown up to an altitude of 3,000 feet, the soils are practically neutral. That is, they do not show the acidity characteristic of mauka soils. Acid mauka soils are characterized by low availability of plant food and sluggish biological life, both of which are stimulated by neutralization of soil acidity.

During the past two years we have devoted considerable time to an investigation of the factors associated with the low fertility of the soils of Kilauea plantation. From a close observation of the poorer soil types located on this plantation, few there are who would fail to suggest lime as one soil amendment in any programme of fertilization. The soils contain a highly colloidal form of clay, which is in a high state of dispersion, and they are, in the main, acid soils. So it is not surprising that during the last twenty years coral sand has been applied many times to Kilauea fields, but with variable results. Often the spots in the fields where the lime had been piled preparatory to broadcasting—such spots would be heavily limed—gave notable response. But in other fields serious injury to cane growth on such spots was noted. Similar variation has been noted in field experiments, and no materially profitable return has been obtained. The fact that in some cases response has been noted, coupled with our knowledge of the general character of Kilauea soils, has led us to still feel that an improvement in fertility should involve applications of lime in some form. The records on file covering lime experiments at Kilauea show that out of seventeen observations nine gave some response, either in the spots where the lime was piled for broadcasting or in the broadcasted areas, while eight gave none or injured the cane growth. The amounts applied varied from half a ton per acre to as high as thirty-six tons per acre, and no relation between soil reaction or soil type and response was evident.

The same is more or less true of lime experiments conducted in other parts of the islands by the Experiment Station, in that harvesting results have not per-

mitted definite interpretations regarding the effect of lime. There has been evidence of response to lime on neutral soils. On acid soils there has been little to lend encouragement to the advocates of liming (6). The question therefore arises, have we sufficient understanding of the nature of our soil acids, and have we properly satisfied the lime requirement of our soils, or have we overlooked other essential, associated, growth-limiting factors which may be present in our acid types?

It is well known and widely recognized that many plants prefer and grow best at rather closely defined ranges of soil reaction, and that for most plants, where little preference is shown, a reaction of approximately pH 6.5 is most suitable. We have no direct evidence of soil reaction preference in sugar cane, but the comparative growth of cane in the neutral mauka fields of Kau and the acid mauka fields of Hamakua suggests a reaction near neutrality. However, for the present let us drop the more specific reaction preference of the cane plant, which would be greatly complicated by the number of cane varieties which we grow, as well as the difference in lime requirement of the plant, and take up the lime requirement of the soil, that is, the amount of lime required to bring the soil to neutrality or some other definite reaction. Except for a few acid-loving-calcifuge-plants, most crops are not at their best in an acid soil environment and hence for centuries it has been the practice to "sweeten" acid soils with lime, one of our oldest fertilizer materials.

Methods for the determination of the lime requirement of the soil are legion, but few, if any, have been extensively adopted in spite of the fact that in specific cases some one method has been used to advantage. We have, therefore, attempted in connection with our Kilauea soil investigations, to first seek some fundamental information regarding acidity in our island soils. There are, at Kilauea, soils on which lime has shown both response and injury, so that conditions there present an excellent opportunity for gaining some rather definite information on the liming problem.

Soil Acidity

Soil acidity has been variously attributed to physical adsorption, chemical absorption, free hydrogen ions, presence of silicic acid, hydrolysible salts of iron and aluminum, organic acids, and the complex silicates known as zeolites, which are components of the colloidal clay fraction of the soil sometimes referred to as the alumino-silicate complex.

The first conception of soil acidity involved the presence of the so-called humus acids, formed from the decomposition of plant remains. Later, the absorptive property of the soil was recognized, to which was attributed the change in color of litmus paper when used for testing the soil reaction. As our knowledge of soil acidity broadened, evidence of several types of acidity appeared and we had:

1. True, active, or free acidity from such acids as nitric, sulphuric or hydrochloric, sometimes referred to as soluble acidity.

2. Interchange or exchange acidity released from the soil by salts of strong acids and believed by some to be due to the interchange of basic ions for iron

and aluminum, the salts of which, when in solution, will hydrolyze with an acid reaction.

3. Hydrolytic acidity developed in the hydrolytic splitting off of salts of weak acids.

The situation was later further complicated by the use of such terms as actual acidity and potential acidity. The former term applied to the free hydrogen ion concentration, or pH, and the latter to the amount of base required to completely saturate the soil.

It is now gratifying to note that the above more or less confusing array of terms and forms of acidity has been greatly clarified by the latest advances in soil research and, too, greatly simplified. In other words, it is now definitely established that soils contain alumino-silicate complexes, components of the colloidal clay fraction of the soil, which are the seat of absorption or ionic exchange phenomena and are, in large part, involved in all changes in soil reaction. In fact, some of the leaders in soil research go so far as to now maintain that all soil acidity is essentially as above and of one kind(5).

There may be present in this absorptive component of clay, bases such as calcium, magnesium, sodium and potassium, or the hydrogen ion, all of which are subject to exchange with other soluble bases or hydrogen of a solution with which the clay may be brought in contact. All soils have a rather definitely defined capacity for absorption, usually referred to as the saturation capacity. In most part calcium is the predominant base, and such soils are usually the fertile types. Any deviation from this condition often works to seriously injure the soil properties, black alkali soils being types in which the complex is in large part combined with sodium. If the saturation capacity is in certain part combined with hydrogen, soil acidity is manifested. There is a notable variation in the affinity which the absorbing complex—the clay—shows toward different bases and hydrogen, and it is greater for hydrogen than for any of the bases. Therefore, even such weak acids as carbonic acid, present in rain water, and the organic acids formed in the decomposition of plant residues, are extremely active in the replacement of bases in the soil. These are the conditions found in our mauka fields and have been largely involved in the development of acidity in these areas. Added to this, there has been a notable depletion of soil bases, such as calcium which, too, makes for greater absorption of hydrogen.

Experimental

In the correction of soil acidity, or the liming of soils, it becomes of fundamental importance to have some knowledge of the saturation capacity of the soil and to know in what part this capacity is satisfied by bases and with hydrogen. The exchange property of the absorbed bases of the clay is such as to be greatly and easily modified by contact with solutions of salts or acids. Thus it is possible to remove all other absorbed bases or hydrogen by leaching the soil with a definite soluble basic salt and, by analyzing the leachate, to determine the nature of the absorbed ions. This method has therefore been universally adopted for determining the absorbed or replaceable bases and hydrogen in soils.

On account of the difference in affinity of the absorbing complex for bases and hydrogen, some salts are more active as replacing agents than others. This is especially true of the replacement of hydrogen and there is a notable difference, also, in the rate of hydrogen replacement by the salts of strong acids, such as calcium chloride, and the salts of weak acids, such as calcium acetate.

For a study of some of these factors and of the properties of our acid island soils, four widely varying and representative types were selected.

1. Red clay soil, pH 4.8 characteristic of the acid clay soils of the islands and which types are found in lowest pH or of highest acidity.

2. Yellowish brown silt loam from Honokaa plantation pH 5.5. This acid soil is well supplied with organic matter, but less than soil number 3 and from a less humid district.

3. Black highly organic silt from Olaa plantation pH 5.7. This is a soil of comparatively recent formation, very high in organic matter, and from one of our most humid districts.

4. Heavy black acid clay type pH 5.8. This soil, as an additional deviation from normal, also contains unusually large amount of replaceable magnesium.

Four salt solutions of the following concentration were used for the replacement of the hydrogen. Normal ammonium chloride; normal potassium chloride; twice normal, normal and tenth-normal barium chloride; and normal and tenth-normal barium acetate.

Twenty-five grams of air-dried soils were weighed into glass cylinders, one inch diameter, especially adapted for leaching soils with salt solutions. The soil columns were leached with successive 100 c.c. portions of the salt solutions, and each 100 c.c. leachate titrated with standard alkali, using the quinhydrone electrode. Readings were taken with the electrode at successive additions of alkali, and the data are presented graphically in Figs. 1, 2, 3, 4, in lieu of presenting the large amount of tabulated data.

Each titration curve is designated as 100, 500, etc., representing the titration of the first 100 c.c., fifth 100 c.c., etc., of leachate. In cases where there was little or no variation in the titration of successive leachings, such as was the case with the chlorides, some of the curves are omitted for the clarity of the graph. These graphs show the reaction of the displaced solution, the rate of hydrogen replacement, and the total amount of hydrogen displaced is shown by the volume of standard alkali required to bring the displaced solutions to neutrality.

The purpose of the experiment was not quantitative, but rather to obtain information regarding the comparative replacing power of the salts of strong acids and the salts of weak acids, and to learn something of the comparative properties of our acid clay soils and acid organic soils.

It is quite evident that our island acid soils are potentially highly unsaturated, that is, unsaturated with respect to bases. The organic soils show only very small amounts of so-called exchange acidity, that is, acidity replaced by the salts of the strong acids, while considerably more hydrogen is displaced from the acid clay by these salts. These data indicate that it would be impossible to replace the hydrogen with a chloride within any reasonable time limit. However, when leached with barium acetate, the salt of both a weak acid and weak base, the replacement was

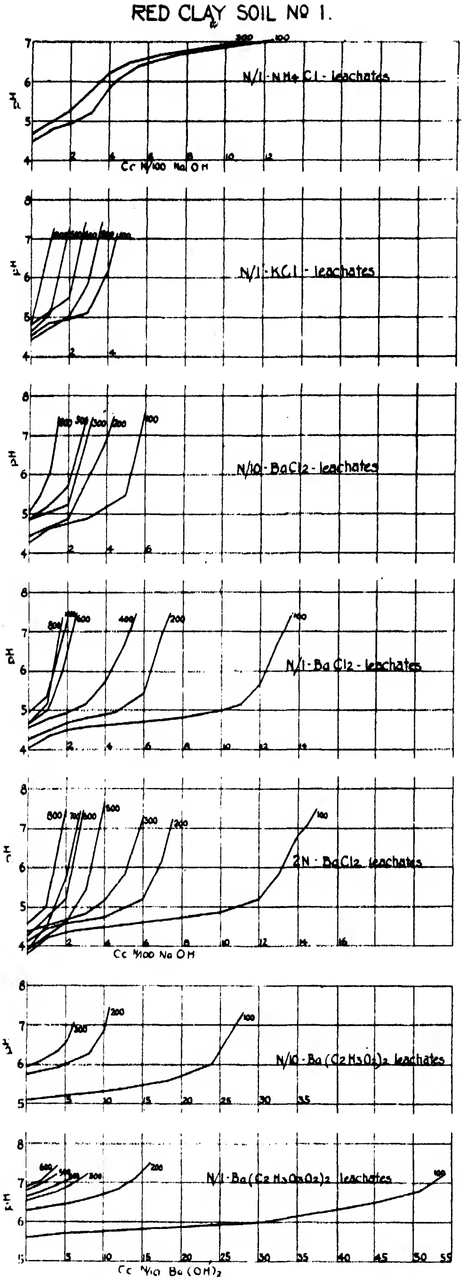

Fig. 1

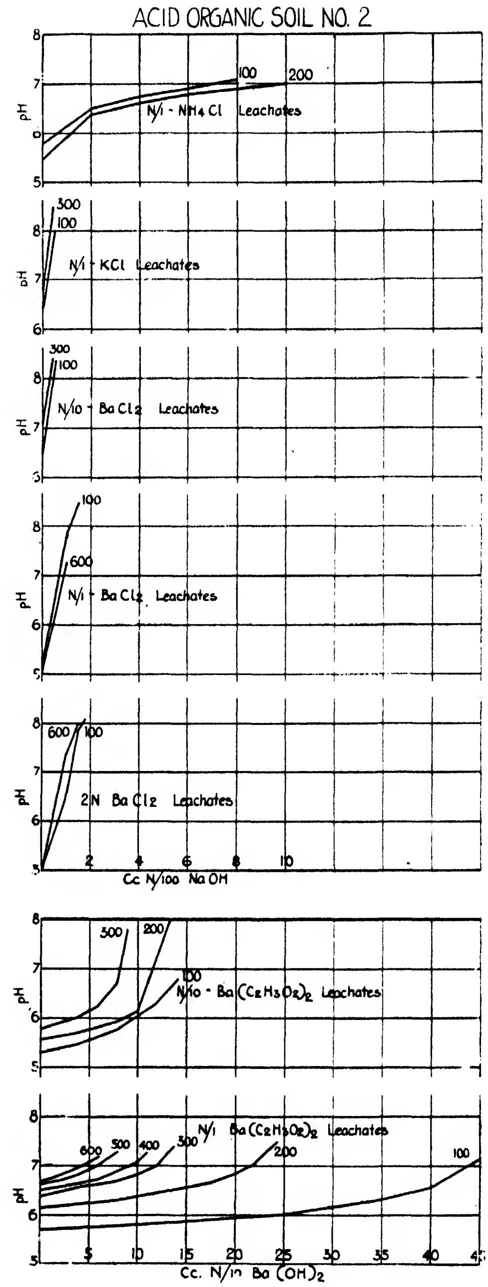

Fig. 2

apparently complete. This shows that the acidity of our island soils is largely the so-called hydrolytic acidity. The ratio of amount of hydrogen replaced in the first 100 c.c. of normal barium chloride to that replaced by the first 100 c.c. of barium acetate is of interest, and is as follows:

Soil No. 1	1:41
Soil No. 2	1:630
Soil No. 3	1:265
Soil No. 4	1:300

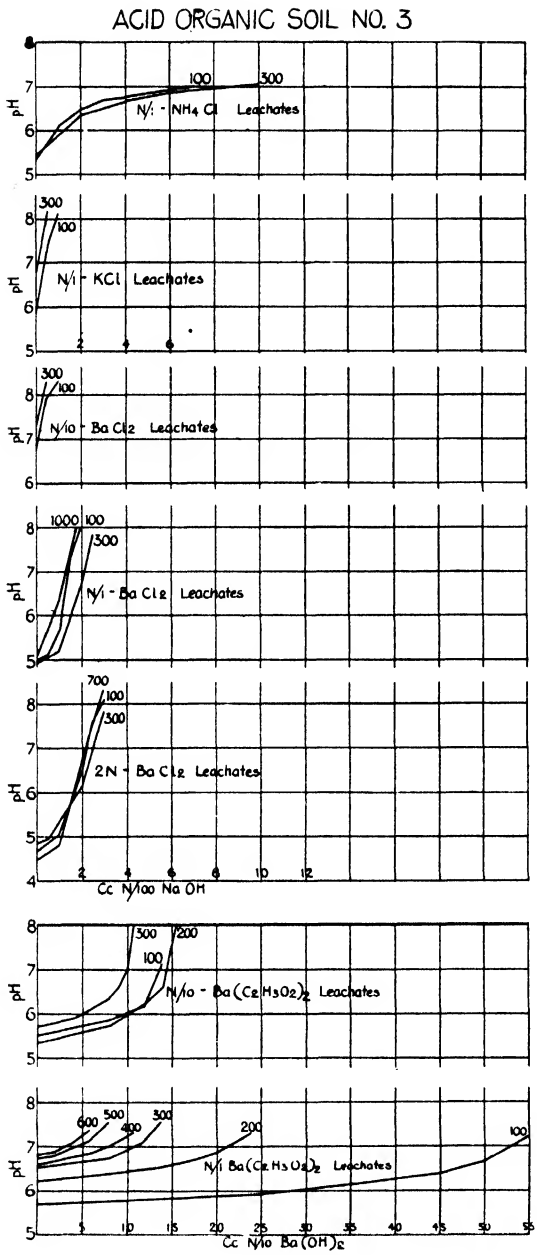

Fig. 3

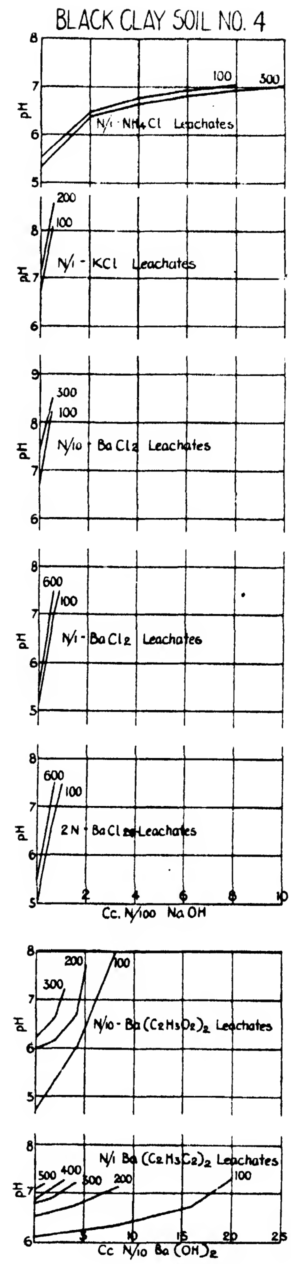

Fig. 4

On the basis of the above we should expect a more active acidity in the acid clays and a higher equilibrium concentration for soil hydrogen.

Quantitative

It is evident from the preceding experiments that any quantitative determination of the degree of unsaturation, or the replaceable hydrogen content of our Island soils, should involve the use of a basic acetate. Barium being the most active replacing base, the acetate of this salt is to be preferred, also, that a normal solution be used and as small a sample of soil as possible be employed. From the

amount of N/10 alkali used in the titration of the leachates from 25 grams of soil, it is evident that 5 grams of soil is ample.

Some investigators have recommended normal barium chloride for the quantitative determination of replaceable hydrogen, leaching the soil until the leachate no longer shows acidity, and among these are Gedroiz(2) and Joffe and McLean(4). Such a method appears to be entirely unsuited to local soils and is an endless procedure, if even possible at all, which is to be doubted. The replacement of hydrogen or its exchange properties are materially affected by the hydrogen ion concentration of the leaching solution. Salts of strong acids, such as the chlorides, which are highly ionized and poorly buffered, will therefore have very weak replacement properties for hydrogen in acid soils. This is because sufficient hydrogen ions will be present to prevent the replacement reaction going to completion. Barium acetate is the salt of a weak acid. Solutions of this salt have a very low ionization value, and are highly buffered. Therefore the replacement reaction between barium acetate and fixed hydrogen will proceed rapidly toward completion.

Through communication with W. P. Kelley, Citrus Experiment Station, Riverside, California, and F. W. Parker, Alabama Experiment Station, we learned of their investigations on this same problem and they kindly submitted quantitative methods which they had developed. In one case Parker determines the exchange capacity of the soil, the exchange base content, and then calculates the replaceable hydrogen by difference. In another he leaches the soil with a neutral solution of barium acetate and titrates the leachate in the same manner used by us in our preliminary work, thus determining the replaceable hydrogen direct:

Exchange capacity of soil: Five grams of soil are treated at room temperature with 100 c.c. of N/10 $Ba(OH)_2$, for a period of 16 to 18 hours. The whole is then filtered by suction through a Gooch crucible, the soil too being transferred. The soil in the crucible is then leached with 250 c.c. of N/1 NH_4Cl, then carefully washed with ethyl alcohol until free from chlorides. The NH_4 fixed by the soil is then determined which represents the total replacement capacity of the soil.

Exchangeable base content: Five grams of soil are placed in a Gooch crucible and leached with 250 c.c. of N/1 $BaCl_2$. The leachings are titrated with N/10 $Ba(OH)_2$ to determine the amount of hydrogen replaced by the barium. The soil is then leached with N/1 NH_4Cl until the leachings no longer give a test for barium and the barium determined as $BaSO_4$. Expressed in chemical equivalents, the amount of barium absorbed minus the hydrogen replaced gives the replaceable base content of the soil.

Barium acetate method: Five grams of soil are placed in a Gooch crucible and leached with 250 c.c. of N/1 $Ba(C_2H_3O_2)_2$ and the leachings titrated electrometrically to pH 7.0. It is essential that the reaction of the barium acetate used for leaching the soil be exactly neutral.

It is of interest to mention that Parker found a complete replacement of hydrogen by his barium acetate method.

Using the same four soils as employed in our preliminary experiments, determinations being made in duplicate, the following results expressed in milliequivalent terms were obtained*:

* We have adopted the plan, throughout this paper, of expressing results on a milliequivalent basis (M. E., milligram equivalents per 100 grams soil), so that any base is directly comparable with another or with hydrogen in the proportion by weight at which they are capable of replacing each other or of combining with other ions to form salts.

TABLE I

Showing Replacement Capacity and Replaceable Hydrogen by Parker Method

Soil Number	1	2	3	4
Total exchange capacity	25.0	51.9	48.3	63.5
Barium fixed by soil	8.36	14.94	17.55	53.33
Hydrogen in $BaCl_2$ sol.	4.8	1.1	3.0	1.0
Total bases by difference	3.56	13.84	14.55	52.33
Replaceable hydrogen by difference	21.44	38.06	33.75	11.17
Replaceable hydrogen by titration $Ba(C_2H_3O_2)_2$	20.99	27.77	24.80	8.92

In the method submitted by Kelley the soil is treated with N/10 $Ba(OH)_2$, as in Parker's method, and leached with a neutral solution of N/1 ammonium acetate as long as the leachate shows a test for bases. The soil is then leached with a neutral solution of methyl* alcohol until the leachate is free from NH_4, and the total ammonium absorbed determined, which represents the total replacement capacity. The difference between this and replaceable bases in the soil represents replaceable hydrogen. The results obtained by this method are given below as milliequivalents:

TABLE II

Showing Replacement Capacity by Two Methods

Soil Number	1	2	3	4
Total replacement capacity—Kelley	25.4	51.7	48.3	63.6
Total replacement capacity—Parker	25.0	51.9	48.3	63.5

All the salt solutions used in the above were carefully neutralized to pH 7.0 before the leaching. Determinations were all made in duplicate and good checks were obtained. The two methods give very closely agreeing results considering the high saturation capacity of the soils used. On the other hand, there is a serious discrepancy in the replaceable hydrogen as determined by titration and by the difference method of Parker. Kelley does not specify in what manner the total replaceable base content shall be determined, but, if we use the method suggested by Parker, the following results as milliequivalents are obtained:

TABLE III

Showing Replaceable Hydrogen by Difference and by Titration

Soil Number	1	2	3	4
Total replacement capacity—Kelley	25.4	51.7	48.3	63.6
Total bases—Parker	3.5	13.8	14.5	52.3
Replaceable hydrogen by difference	21.9	37.9	33.8	11.3
Replaceable hydrogen by titration	20.9	27.7	24.8	8.9

For example, if a soil contains 0.400 per cent calcium we would express this on a milli-equivalent basis as follows:

$$\frac{\text{milligrams per 100 grams soil} — 400}{\text{atomic weight} — 40.07} \times \text{valency} — 2 = \text{M. E.} — 19.96.$$

---

* Methyl alcohol is a non-hydrolizing and coagulating solvent.

Here it is noted that in soils 1 and 4 there is close agreement, but wide discrepancies in soils 2 and 3.

In order to confirm this apparent error, the replaceable bases sodium, potassium, calcium and magnesium were carefully determined by displacement with normal solutions of ammonium chloride and ammonium acetate and tenth normal solutions of barium chloride and barium acetate. All these salt solutions gave closely agreeing results and those obtained with ammonium acetate are given in the following table:

TABLE IV

M. E. Replaceable Bases

Soil No.	Sodium	Potassium	Calcium	Magnesium	Total
1	.90	.6	2.0	1.1	4.6
2	1.31	.7	8.0	2.5	12.5
3	1.44	.7	10.6	2.9	15.6
4	5.4	1.2	12.7	35.3	54.6

In Table V the sum of the bases calcium, magnesium, sodium and potassium, in milliequivalents, is added to the hydrogen as determined by titration.

TABLE V

Showing Replacement Capacity by Three Methods

Soil Number	1	2	3	4
Total bases, separately determined	4.6	12.5	15.6	54.6
Hydrogen by titration	20.99	27.77	24.8	8.92
Total replacement capacity	25.59	40.27	40.4	63.5
Total replacement—Parker Method	25.0	51.9	48.2	63.5
Total replacement—Kelley Method	25.4	51.7	48.3	63.6

Only in two soils, 1 and 4, does the sum of the bases and hydrogen agree with the total replacement capacity as determined by preliminary neutralization of the soil acidity with barium hydroxide.

Following the above we next took a slightly alkaline soil, a red clay type from Ewa plantation, Oahu, reaction pH 7.8, and followed the same analytical procedure as above, with the following results:

TABLE VI

Showing Replaceable Bases and Replacement Capacity of Neutral Clay Soil

Replaceable calcium	6.0
Replaceable magnesium	6.8
Replaceable sodium	1.3
Replaceable potassium	0.4
Replaceable hydrogen—barium acetate	0.0
Total replaceable bases	14.5
Replacement capacity—Parker	13.9
Replacement capacity—Kelley	13.9

While the total replacement capacity of this soil is less than the acid soils, the agreement between the three methods is nevertheless quite close. On leaching this soil with neutral barium acetate the leachate had the same reaction using the quinhydrone electrode, as the original solution, showing no replaceable hydrogen.

There is much evidence in the preceding data that a preliminary treatment of the soil with barium hydroxide will, in some acid soils, show a fixation of base in excess of the saturation capacity of the soil. It is significant that soils 2 and 3, which show this property, are highly organic types. Organic matter may therefore be associated with "excess" base absorption. Among other possible associated factors may be included, replaceable iron and aluminum, hydroxyl ion fixation, fixation as basic salts or aluminates, and the conversion of barium hydrate into barium carbonate by the carbon dioxide in the air.

The comparative organic matter present in these soils was determined as total carbon, and the results are given in the following table:

TABLE VII

Showing Per Cent Carbon in Soils

Soil No.	Total Carbon Per Cent
1	4.99
2	9.69
3	13.60
4	3.00
5	1.22

These data show an apparent relation between "excess" fixation of base and give further evidence that the soil organic matter is in some way involved.

The higher saturation capacity obtained where the soils receive a preliminary treatment with barium hydroxide strongly indicates that there is, at least in part, an hydroxyl absorption by the soil. This is further shown by the following experiment: Five-gram portions of the five soils were weighed in duplicate: one sample was placed directly in Gooch crucibles and leached with 250 c.c. of normal barium acetate, then washed with neutral methyl alcohol until free of soluble barium, and finally leached with 250 c.c. of neutral ammonium acetate. The barium was determined in the leachate, and the ammonium fixed by the soil was determined after carefully washing the soil with neutral methyl alcohol until the leachings were free from ammonium. The other set of samples was weighed into Erlenmeyer flasks, 100 c.c. of N/10 barium hydroxide added, the whole shaken occasionally for 18 hours, the contents then transferred to a Gooch crucible and washed with neutral methyl alcohol and then with neutral normal ammonium chloride. The barium was determined in the leachate, and the ammonium fixed by the soil was determined after washing the soil free of ammonium chloride with neutral methyl alcohol. The results are given in the following table:

TABLE VIII

Showing "Excess" Base Fixation from Barium Hydroxide and Barium Acetate

Soil No.	$Ba(OH)_2$ Ba	NH_4	$Ba(C_2H_3O_2)_2$ Ba	NH_4	Sum of Bases and Hydrogen	Sat. Cap. Kelley	Sat. Cap. Parker
1	74.3	25.7	30.1	22.9	25.6	25.4	25.0
2	140.0	51.4	48.0	47.4	40.3	51.7	51.9
3	118.3	50.8	50.7	45.4	40.4	48.3	48.3
4	90.1	62.1	65.4	62.3	63.5	63.6	63.5
5	27.3	14.1	16.3	14.1	14.5	13.9	15.4

Column 1 shows the barium fixed by the soils from an N/10 solution of $Ba(OH)_2$, column 2 the ammonium fixed by the same soils in displacing the barium with neutral ammonium chloride, column 3 the barium fixed from a neutral solution of barium acetate without preliminary treatment with the barium hydroxide, and column 4 the ammonium fixed by these same soils in displacing the barium with neutral ammonium acetate. In the last three columns the total replacement capacities of the soils, as determined by three different methods, are given for comparison. The comparative figures given in column 1 are significant. While it is admitted that it is impossible or very difficult to wash the soils free of barium with neutral methyl alcohol, where the soil has been treated with barium in solution as hydroxide, the greater absorption of barium hydroxide in the organic soils must be admitted beyond question. These soils, too, are the types which give the greatest variations between the replacement capacity determined by preliminary treatment with barium hydroxide and the replacement capacity calculated from the sum of the replaceable bases and hydrogen. The neutral soil, number 5, gives rather consistent results by all methods and shows the least absorption of barium hydroxide, from which we are led to assume that the high replacement capacity, denoted by preliminary treatment with barium hydroxide, is a characteristic of the acid soils. But the fact that the acid clay soils show less of this phenomena than the organic soils would further indicate that we have an error introduced, either by the organic matter or a difference in the properties of our acid clay soil colloids and the colloids in our acid organic soils.

In the following table there is shown a comparison of the total carbon content of the soil and the amount of base fixed in excess of the replacement capacity, and these results show an almost direct relation:

TABLE IX

Showing Relation of Organic Matter to Excess Base Fixation

Soil No.	Total Carbon Per Cent	Excess Base Fixation
3	13.60	67.5
2	9.69	88.6
1	4.99	48.6
4	3.00	28.0
5	1.22	13.2

Soil number 4, a heavy clay soil, with a very high exchange capacity, namely, 63.5 M. E., as well as the neutral clay, number 5, and the acid clay, number 1,

show a lower fixation of barium hydroxide than the organic soils 2 and 3. The fixation of barium hydroxide in excess of the replacement capacity is completely removed on subsequently leaching the soil with a normal solution of ammonium chloride, as shown in column 2 of Table VIII. Furthermore, the replacement capacity of the three clay soils, as determined by this method, closely agrees with the sum of the replaceable bases and hydrogen.

Barium carbonate precipitation can hardly be given serious consideration in view of the closely agreeing results obtained for the three clay soils of low organic content. The same should apply to the possibility of aluminates or inorganic basic salts as all the soils are similar in being laterite types and contain oxides and hydrates of iron and aluminum.

Hissink(3) has used barium hydroxide solution for estimating base unsaturation or replaceable hydrogen in soils. He used both conductrimetric titration and titration with indicators to determine the end point. His method is essentially as follows: A known weight of soil is placed in each of a series of Nessler tubes, to which are added varying amounts of standardized barium hydroxide solution. The tubes are immediately tightly stoppered and shaken several times daily for three days. The soil is then allowed to settle for one day and aliquots of the supernatant solution titrated against standard acid, using phenolphthalein as an indicator. The hydroxide absorbed is considered equivalent to the degrees of unsaturation of the soil.

The application of this method to Hawaiian soils only lends further evidence of hydroxyl absorption beyond unsaturation, or that some other secondary reactions are involved. This is shown in Table X, in which are given data obtained on soils numbers 1, 2 and 5. Five grams of soil were weighed into large glass test tubes, varying amounts of N/10 barium hydroxide added and the volume of water in each brought to the same volume of 100 c.c. They were then tightly stoppered, shaken several times daily for three days, allowed to settle one day, and 50 c.c. of the supernatant solution titrated with N/10 acid, using phenolphthalein as an indicator.

TABLE X

Showing Barium Hydroxide Absorption

Mgms. $Ba(OH)_2$ added per 5 gms. soil	42.8	85.7	171.4	257.1	342.7
Mgms. $Ba(OH)_2$ absorbed 5 gms. soil No. 1	42.8	85.7	167.9	248.5	320.5
Mgms. $Ba(OH)_2$ absorbed 5 gms. soil No. 2	42.8	85.7	171.4	251.9	327.3
Mgms. $Ba(OH)_2$ absorbed 5 gms. soil No. 5	39.4	78.8	137.1		
M. E. $Ba(OH)_2$ added per 100 gms. soil	10	20	40	60	80
M. E. $Ba(OH)_2$ absorbed 100 gms. soil No. 1	10	20	39	58	74
M. E. $Ba(OH)_2$ absorbed 100 gms. soil No. 2	10	20	40	59	76
M. E. $Ba(OH)_2$ absorbed 100 gms. soil No. 5	9.2	18.4	32		

This experiment indicates that not only is the organic matter present in the soil a function of "excessive" base or hydroxyl absorption, but that the concentration of the basic hydroxide solution, with which the soil is in contact, is an additional function. It is believed that no definite conclusions can be drawn from the application of the Hissink method to base unsaturation in Hawaiian soils.

In addition to the hydroxyl absorption shown in column 1, Table VIII, there is also some evidence in column 3 of barium fixation from neutral N/1 barium acetate solution in excess of the saturation capacity of the soil. This is indicated by the "excess" exchange capacity of all the determinations in column 3, and the fact that in the clay soils 1, 4 and 5, the ammonium fixed by subsequently leaching the soils, column 3, with neutral N/1 ammonium acetate agrees very closely with the exchange capacity of the soil, that is, the sum of bases and hydrogen. There is also a further interpretation of the data in Table VIII to the effect that a preliminary treatment of an acid or neutral soil with barium hydroxide is not necessary for a determination of the replacement capacity, but that it is possible to effect a complete saturation by leaching the soil with a basic acetate solution.

In order to investigate this more thoroughly, the organic soil, number 2, and the neutral clay, number 5, were subjected to a number of leachings with barium hydroxide. A description of these treatments is given as follows, and the data obtained are given in Table XI:

1. A ten-gram sample of soil was treated 18 hours with 100 c.c. of N/10 barium hydroxide, washed into a Gooch crucible, leached with 250 c.c. neutral N/1 ammonium acetate, then with neutral N/1 barium acetate and the ammonium determined in the leachings-A. Then leached with 250 c.c. N/1 ammonium acetate and barium determined in the leachings-B. Then leached with 250 c.c. N/1 barium acetate and ammonium determined in the leachings-C. Then with 250 c.c. N/1 ammonium acetate and barium determined in the leachings-D. Then with 250 c.c. barium acetate and ammonium determined in the leachings-E.

2. Treatment in this series was exactly as in 1, except that after the barium hydroxide treatment ammonium chloride and barium chloride were alternated in place of ammonium acetate and barium acetate.

3. Treatment in this series was similar to 1, except that barium acetate was used first after the barium hydroxide and then alternated with ammonium acetate.

4. Treatment in this series was exactly as in 3, except that barium chloride and ammonium chloride were alternated.

5. In this series there was no preliminary treatment with barium hydroxide. The soil was leached in a Gooch crucible with 250 c.c. neutral barium acetate, then 250 c.c. neutral N/1 ammonium acetate and barium determined in the leachings-A. Then with 250 c.c. N/1 barium acetate and ammonium determined in the leachings-B. Then with 250 c.c. N/1 ammonium acetate and barium determined in the leachings-C. Then with 250 c.c. barium acetate and ammonium determined in the leachings-D. Then with 250 c.c. ammonium acetate and barium determined in the leachings-E.

The barium determinations are all underlined in Table XI, while where the amount of ammonium fixed was determined the figures are not underlined. All data are calculated on a milliequivalent basis so that the replacement capacity is directly comparable in all. In all cases, between leachings, the soil was carefully leached with neutral methyl alcohol to remove the excess salt solution.

TABLE XI

Showing Comparative Absorption of Barium and Ammonium from Hydroxide and Acetate Solutions

Soil Treatment	A	B	C	D	E
1	55.5	76.0	52.5	67.4	51.5
2	48.1	64.3	44.5	52.5	40.9
3	154.4	59.2	77.0	52.9	68.3
4	131.4	47.8	63.7	45.2	53.5
5	54.9	46.6	53.2	44.3	59.5
1	22.9	19.5	20.7	17.9	20.4
2	14.7	18.4	13.6	14.1	12.6
3	54.4	21.3	19.8	20.5	21.7
4	37.4	14.5	17.0	13.1	14.6
5	12.2	20.9	15.2	20.3	17.5

These data show that the soil will absorb larger amounts of base from barium acetate than from ammonium acetate, and that this absorption may be, at least in part, as barium hydroxide. For this reason ammonium acetate should be the more desirable salt for determining exchange capacity. The ionization constants for ammonium hydroxide and acetic acid agree very closely, which, as pointed out by Conrey and Schollenberger(1) makes this salt an ideal reagent. The fixation of barium as hydroxide from barium acetate is further indicated by the reaction of the leachates obtained in treating the organic soil in the above experiment. The soil, after 18 hours contact with N/10 barium hydroxide, and washing into the Gooch crucible with neutral methyl alcohol, and then leaching with neutral ammonium acetate, gave a reaction of pH 7.9 in the ammonium acetate leachings. On leaching this soil, then with normal barium acetate, pH 7.05, the leachings gave a reaction of pH 6.9 and, on subsequently leaching this sample with normal ammonium acetate, pH 7.0, the reaction of the ammonium acetate was increased to pH 7.2. An additional experiment was made in which 5 grams of this same soil were leached directly with 200 c.c. of normal barium acetate, pH 7.05, and the leachate was found to have been reduced in pH to 6.7. It was then leached with normal ammonium acetate, pH 7.0, and the leachate had a reaction of pH 7.1, while another leaching with normal barium acetate showed again a reduction of pH to 6.8 in the barium acetate leachate.

We believe we have sufficient data, therefore, to show that preliminary treatment of the soil with barium hydroxide is not necessary to obtain complete saturation, and the fixation of barium from a neutral solution of barium acetate will, like that from a preliminary treatment with barium hydroxide, show fixation in excess of the exchange capacity of the soil. It is recognized that the changes in reaction of the leachates recorded above are very small, but when one considers the low ionization of the acetate of a weak base the pH determination is not a good measure of the changes in potential acidity or alkalinity.

Page(5) has suggested that the replacement of hydrogen ions from the soil-absorbing complex can be carried to completion only by means of an alkaline solution. His suggestion is apparently based upon the fact that the soil complex associated with exchange reactions is salts of strong bases and weak acids and, therefore, more or less hydrolysis is essential for completion of the reaction. On this basis it occurred to us that in our two organic soils possibly we had not obtained complete replacement of hydrogen in the determination made by leaching with neutral barium acetate and titrating the leachate, then adding this to the replaceable bases to obtain the exchange capacity. But this does not harmonize with the fact that the replacement capacity of these two soils, as determined with barium acetate alone, is also greater than that obtained by the sum of the bases plus hydrogen, and agrees with the exchange capacity as determined by preliminary treatment with barium hydroxide. And that furthermore, all the methods when applied to the acid clay soils, one of which is just as high in hydrogen attached to the colloidal complex, give closely agreeing results between exchange capacity and what the capacity is shown to be by adding together the separately determined bases and hydrogen. Our results indicate that the peculiarities in fixing power of the organic soils is not a property of the colloidal zeolite, but rather of the organic matter. While our investigation has shown quite positive evidence of hydroxyl ion absorption, another property of organic matter should be mentioned as possibly being associated with the "excess" absorption of base. Some organic compounds or acids may form highly dispersed colloidal soils or slightly soluble salts with the monovalent bases, while with the divalent bases the salts are either well flocculated compounds like the divalent zeolites, or easily precipitated and entirely insoluble. The soaps of fatty acids may be mentioned as a case in point. We are led to suggest such organic compounds because on leaching the two organic soils with barium acetate, while the amount of barium fixed was greater than the replacement capacity of the soil it was quite consistent. On the other hand, on leaching these soils with ammonium acetate the amount of ammonium fixed, on milliequivalent basis, was less than the amount of barium and, too, the ammonium fixed was not so consistent as the barium.

The data offer a number of valuable suggestions for the quantitative determination of the saturation capacity of our soils. If it is desired to submit the soil to a preliminary treatment with barium hydroxide, then it will be of advantage that the subsequent leaching be made with a neutral normal solution of ammonium chloride. A normal solution of this salt will remove most rapidly the barium fixed as hydroxide, or other side reactions with the absorbing components of the soil, and leave in the soil only the ammonium ions fixed by the soil zeolites. This equilibrium appears to be approached more slowly with acetates or even with barium chloride after preliminary treatment with an alkaline solution, but may be determined accurately with ammonium acetate. The results indicate that a complete saturation of the exchange capacity should be possible through a single leaching with normal ammonium acetate, thus omitting the preliminary treatment with barium hydroxide. Conrey and Schollenberger(1) have already suggested such a method.

As thus applied to the five soils used in our investigation, the following results were obtained:

TABLE XII

Showing Replacement Capacity by Four Methods

Soil No.	Replacement Capacity by Ammonium Acetate	Replacement Capacity by Sum of Bases and Hydrogen	Replacement Capacity Parker Method	Replacement Capacity Kelley Method
1	22.1	25.5	25.0	25.4
2	47.5	40.2	51.9	51.7
3	43.8	40.4	48.3	48.3
4	63.9	63.5	63.5	63.6
5	15.7	14.5	13.9	13.9

With the three clay soils the results agree quite closely. With the two organic soils, due probably to a solubility effect within the components associated with "excess" fixation of base, it was found to be difficult to obtain results that would check with each other. The two figures given in column 1 were arbitrarily selected from a number of determinations which varied from 38 M. E. to 55 M. E.

The conclusion appears inevitable that for our soils low in organic matter regardless of replacement capacity, a direct leaching without any previous neutralization of hydrogen ions with an alkali will give accurate replacement capacity values. But for soils high in organic matter it will be necessary to calculate the replacement capacity by a determination of the exchangeable bases and hydrogen separately. Leaching the soils with normal ammonium acetate, to which ammonium carbonate was added, was also tried on these soils. The results obtained checked very closely on the clay soils, but on the organic soils, 2 and 3, "excess" fixation was again noted. This lends further evidence that a strongly alkaline solution is not necessary for complete saturation when the leaching is made with ammonium acetate.

The methods which gave accurate results are summarized below:

Replaceable bases: Weigh 10 grams soil into a Gooch crucible, asbestos matted, and if a saline type leach with neutral alcohol, either methyl or ethyl, to remove soluble salts. Now leach with 250 c.c. of neutral normal solution of ammonium acetate. All leaching operations are conducted with filtering flasks using a slight vacuum. The entire leachate is then transferred to a porcelain casserole and evaporated on the steam bath to dryness. Ammonium acetate is completely volatile at steam bath temperatures. The residue is then taken up in dilute hydrochloric acid, and the bases determined by any standard methods. We prefer to use two separate 10-gram portions, one for calcium and magnesium and the other for sodium and potassium.

Replaceable hydrogen: Weigh either 5- or 10-gram samples into Gooch crucibles, depending upon the amount of replaceable hydrogen present in the soil, and leach with 250 c.c. of neutral normal barium acetate. Barium acetate is to be preferred to ammonium acetate, because in titrating the end point is more sensitive. The entire leachate is then transferred to a 400 c.c. beaker and titrated elec-

trometrically, using, preferably, the quinhydrone electrode. We prefer, in view of the buffering properties of acetates, to employ the following procedure: A chart or graph is prepared of ordinary coordinate paper with c.c. N/10 $Ba(OH)_2$ as abscissae and potentiometer readings in voltage or pH values as ordinates, or vice versa. The barium acetate to be used for leaching is adjusted to as near neutrality as possible, its pH or potentiometer reading determined, and at this point on the chart a horizontal line drawn. In titrating the leachates from the acid soils, the original potentiometer reading is taken. Tenth-normal $Ba(OH)_2$ solution is then added from a burette, one c.c. at a time thoroughly agitated after each, and the change in potentiometer reading or pH recorded. The data thus obtained are plotted graphically and the point where the curve cuts the horizontal voltage line of the neutral barium acetate is taken as the end point and, from this indicated number of c.c. N/10 $Ba(OH)_2$ used, the hydrogen ions are calculated. A number of determinations are given in Fig. 5 to illustrate.

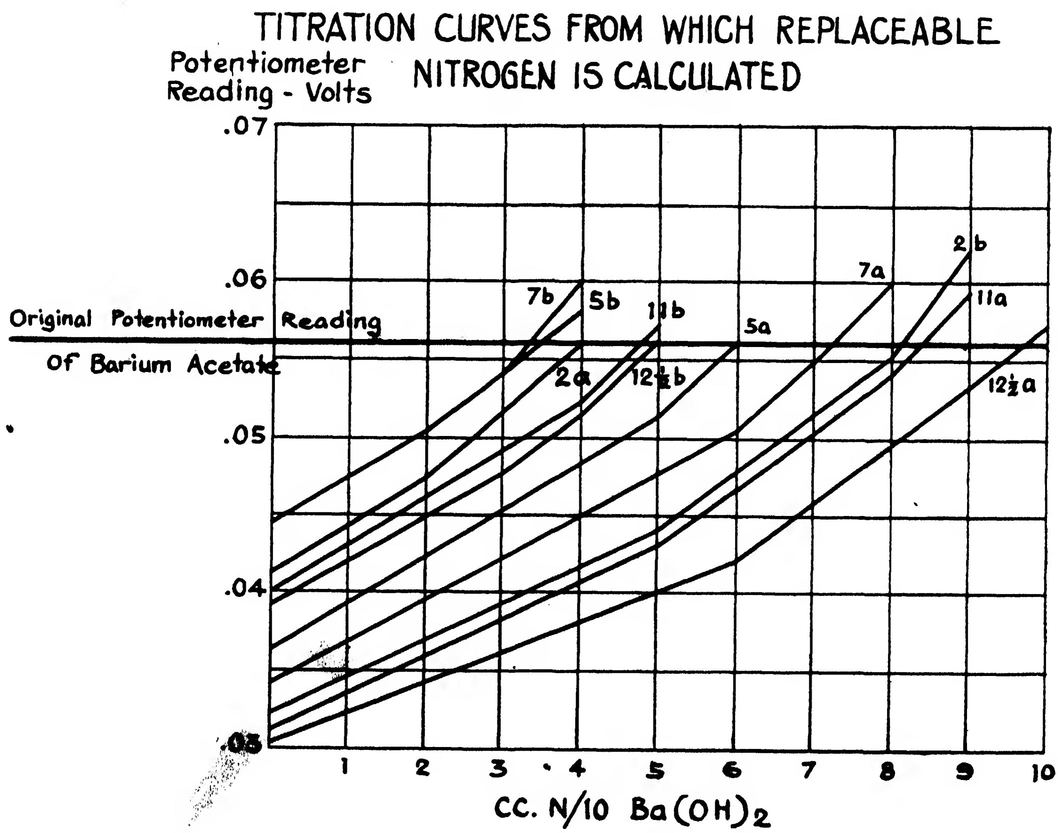

Fig. 5

Replacement capacity: For clay soils, weigh 5 grams of soil into a Gooch crucible and leach with 250 c.c. of neutral normal ammonium acetate. Wash free of ammonium acetate with carefully neutralized methyl or ethyl alcohol, and determine the ammonium fixed by the soil by distillation with magnesium oxide in the usual manner.

For highly organic soils the replacement capacity is best estimated by determining the total replaceable bases separately, or by the barium chloride method

outlined by Parker, and the hydrogen by displacement with barium acetate. The total replacement capacity is equivalent to the sum of the bases and hydrogen.

The above methods have been applied to a number of soils and subsoils taken from Kilauea plantation, and the results obtained are entirely satisfactory, as shown by the data given in the following table:

TABLE XIII

Showing Replaceable Hydrogen and Replacement Capacity, Kilauea Soils

Soil No.	Replaceable Hydrogen	Replacement Capacity by Ammonium Acetate	Replacement Capacity Sum of Bases and Hydrogen
2a	4.0	17.2	21.4
2b	8.2	14.3	16.2
5a	6.0	14.0	15.0
5b	3.8	7.1	8.4
7a	7.3	21.3	26.0
7b	3.3	9.2	10.4
11a	8.2	17.2	18.2
11b	4.8	10.3	10.0
12½a	9.8	16.4	17.9
12½b	5.0	9.8	9.0
14a*	none	16.7*	22.0*
14b	1.3	13 2	13.9
16a	10.2	18.1	20.7
16b	4.6	11.2	8.8
21a	4.9	20.2	21.1
21b	1.0	10.0	8.7
24a	2.4	21.1	26.6
24b	7.5	11.2	11.5
28a*	none	16.9*	22.1*
28b	8.0	13.6	12.8
33a	7.8	27.2	29.8
33b	10.6	16.0	
37a*	none	18.4*	26.2*
37b	4.7	11.7	10.6

Kilauea soils vary greatly in their degree of unsaturation with respect to bases, the least being 10 per cent and the greatest unsaturation being 65 per cent. There is also a wide variation in the total replacement capacity, namely, 27.2-14.0 M. E. in the surface soils, and 16.0-7.1 in the subsoils. The effect of coral sand is shown in Fields 14, 28 and 37, in which the hydrogen has been completely replaced by the calcium from the coral sand. It is very significant that in spite of the many years sand has been on these soils, the subsoils, the second foot, still contain active hydrogen ions. There is no correlation between either replacement capacity or degree of unsaturation and crop performance on these fields.

* Coral sand present in soil.
a Surface soil.
b Subsoil.

Summary

The acidity of Hawaiian soils has been studied with special attention being given to the acid aluminum silicates. To these compounds are attached the so-called replaceable hydrogen ions.

Replaceable hydrogen is not readily displaced from Hawaiian soils by chlorides, but is readily and completely displaced by weakly dissociated acetates. Our soils are therefore high in so-called hydrolytic acidity, and low in so-called exchange acidity.

Replaceable hydrogen, in island soils, may be accurately determined by leaching the soil with neutral normal barium acetate and titrating the leachate, electrometrically, with N/10 alkali.

Our acid soils are apparently highly unsaturated, that is, unsaturated with respect to bases.

Some time has been devoted to studying the saturation capacity of our soils, that is, their capacity for fixing bases. The preliminary treatment of the soil with an alkaline solution is not necessary for complete saturation with base if the soil is leached with a neutral acetate solution. They will absorb barium in excess of their replacement capacity when in contact with a solution of a barium hydroxide.

The highly organic soils show a saturation capacity as measured by base absorption, which is in excess of the sum of fixed hydrogen, calcium, magnesium, sodium and potassium. Data are presented to show that organic compounds are associated with this excess base absorption.

The methods developed or selected from other investigations which were used throughout this work, and which gave very accurate and reliable results for replaceable hydrogen, replaceable bases, and replacement capacity, are given.

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Electrodialysis of Hawaiian Soils*

By W. T. McGeorge

Electrodialysis was used by Cameron and Bell as early as 1905 in studying the mineral constituents of the soil solution. With revived interest in the phenomena of fixation and base exchange in soils, electrodialysis has recently commanded considerable attention, notably by Mattson(3), Bradfield(1), and Humfeld and Alben(2), in the United States as well as by several foreign investigators.

The apparatus used consists of a three-compartment cell, which may be made from an ordinary automobile battery sawed into three sections, each section being cut to a desired size to fit the purpose. These are then drilled to take either five or seven brass rods, so that the two outside chambers may be separated by the membrane enclosing the soil-water suspension and the whole cell clamped tightly to prevent leakage. Provision, of course, must be made for removing the dialysate. The apparatus is illustrated in Fig. 1.

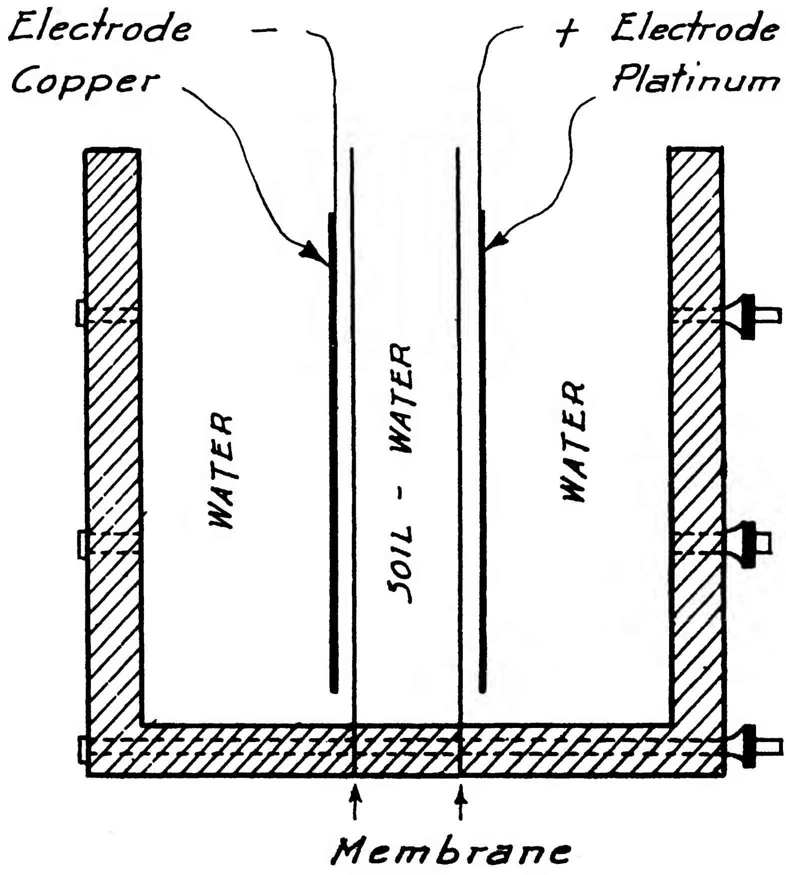

Fig. 1

* In an accompanying article on Availability of Potash, mention was made of the use of the process of electrodialysis for the study of plant food availability in soils. A large part of this work on electrodialysis has been devoted to potassium and is closely related to, and of interest in connection with, an accompanying article on Availability of Potash.

Of the dialyzable compounds present in soils the soluble salts, both the basic and acid ions, will dialyze readily, but the amount of these present in many soils is relatively small. In the main, the major part of the dialyzable material is derived from the less soluble compounds capable of hydrolysis and ionization, namely, the colloidal zeolites. The anion of the zeolite complex, being of colloidal dimensions, is too large to pass through the membrane and, therefore, only its bases are obtained by dialysis with the colloidal anion remaining within the membrane-enclosed chamber. This suggested electrodialysis as a means of studying and determining the zeolite absorbed bases, and it has been shown by both Bradfield(1), and Mattson(3), to give results agreeing closely with those obtained by replacing the bases with concentrated salt solutions. In view of this, we were interested to know how Hawaiian soils would respond to electrodialysis, especially the zeolite potassium as well as the potassium fixed from fertilizer applications.

A chamber of the type shown in Fig. 1 was prepared, using parchment paper as a membrane. For converting A. C. into D. C. a set of four cells was used, each composed of a lead and an aluminum electrode immersed in a solution of ammonium phosphate.* When connected with a 110 A. C. circuit, a current of 50-75 volts with an amperage of less than 1 was obtained in the dialyzing cell. Later, two Westinghouse rectigons and a rheostat were used and compared singly and together in series with the above rectifier.

Experimental

The soils selected for study included a number of island types of widely varying properties and were as follows:

3—26—A black clay soil from Ewa Plantation.
4—Kaneohe—An acid red clay loam from windward Oahu, low fertility.
5—MgZ—A black clay soil, Federal Experiment Station, high in magnesium zeolite.
6—A2D—An acid subsoil, Ewa Plantation Company.
7—2827—Field 28, Kilauea Plantation, experimental potash plot, received 1,500 pounds K_2O per acre from mill ashes, yellow clay soil, poor fertility.
8—2828—Check plot adjacent to 2827, received no potash.
9—2830—Field 28, Kilauea Plantation, check plot in a potash experiment, yellow clay soil.
10—2831—Potash plot, adjacent to 2830, 600 pounds K_2O per acre from mill ash.
11—2835—Field 25, Kilauea Plantation, check plot in potash experiment, yellow clay soil.
12—2836—Potash plot, adjacent to 2835, 1,000 pounds K_2O per acre from mill ash.
13—Waipio K—Potash plot from Experiment V, Waipio substation.
14—Waipio X—Check plot from Experiment V, no potash, Waipio substation.
15—Pahala—A very fertile soil, highly organic silt from Hawaiian Agricultural Co.
16—Hilo—A yellow acid clay from Hilo Sugar Co., which responds readily to potash.
17—19B—A red clay loam from Ewa Plantation, well supplied with available potash.

Rate and Amount of Dialyzable Bases

In all cases 100 grams of soil were used for dialysis. The water was periodically removed from the outside chambers, usually after 2, 4, 6, 9 and 24 hours

* For the preparation of this apparatus as well as the dialyzing cell, the writer is indebted to W. W. Nichols, formerly of the sugar technology department.

and then every 24 hours until dialysis was complete. Each of these fractions was analyzed separately for calcium, magnesium, sodium, and potassium in order to obtain the rate of dialysis as well as the amount of dialyzable bases. In lieu of presenting the large amount of analytical data obtained in this experiment, the rate of dialysis is shown graphically in Fig. 2.

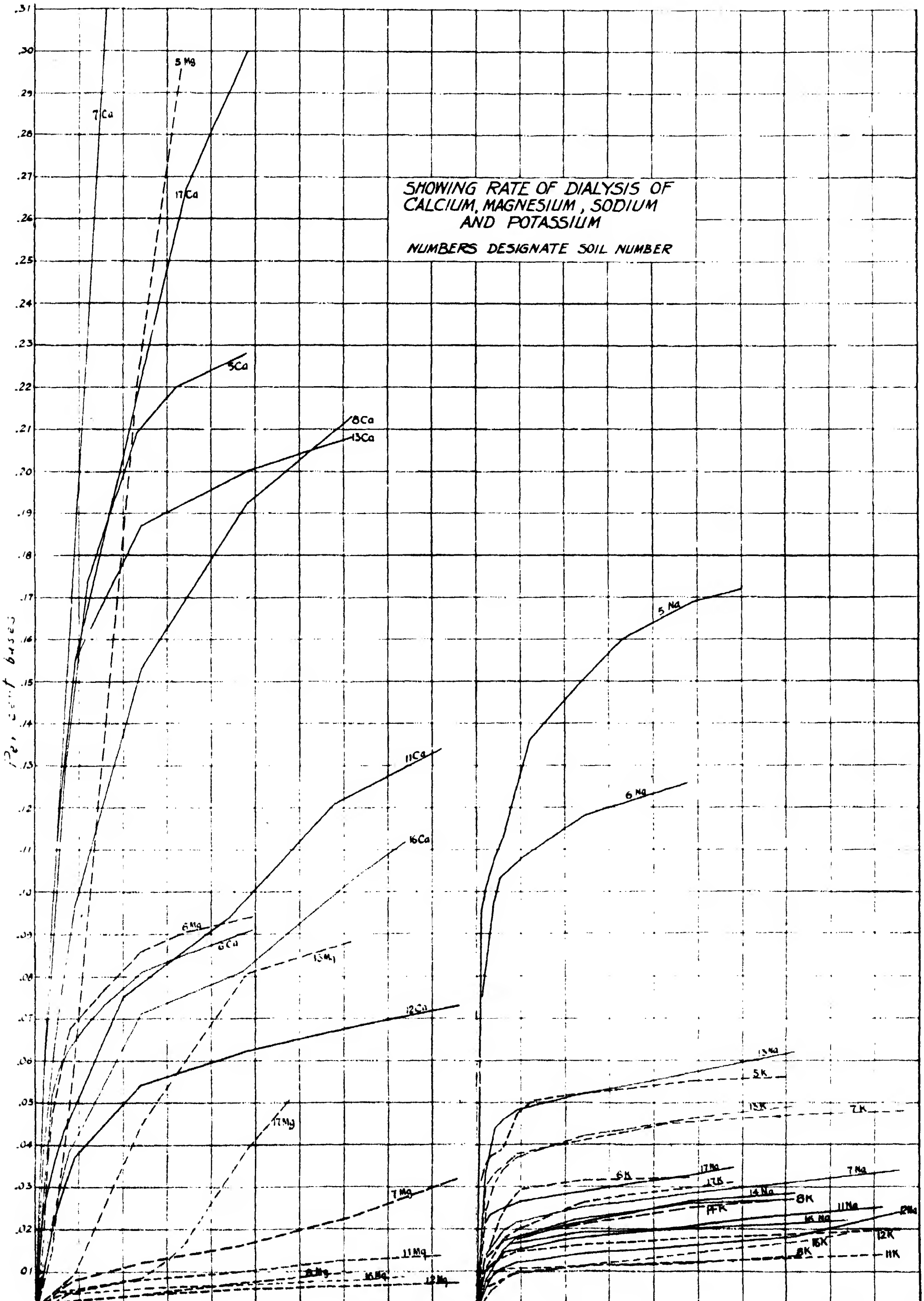

Fig. 2

It is evident from these graphs that practically all the sodium and potassium is removed within a period of a few hours, as shown by the rapidity with which the curves flatten out. While not as quickly removed as the sodium and potassium, calcium is nevertheless very rapidly dialyzed considering the excess of zeolite calcium that is present in all soils. On the whole, magnesium is removed very gradually. This may be due to the characteristic instability of magnesium hydroxide. All the bases in the cathode chamber are present as hydroxides, and the hydroxide of magnesium is only very slightly soluble unless ammonium salts are present in the solution. For this reason it is rather difficult to obtain an accurate measure of the rate of dialysis of magnesium where the magnesium content of the soil is high. It will precipitate upon the walls of the chamber, upon the electrode and upon the walls of the parchment. The slow dialysis of magnesium during the initial period of dialysis is peculiar to the neutral or alkaline soils, while in the acid soils it dialyzes more rapidly. This is because a certain hydrogen ion concentration is essential for holding the magnesium in solution until it passes through the membrane, hence, where other bases are present in large excess, these must first be largely removed to permit a rapid dialysis of the magnesium.

Comparison of Replacement and Dialysis

A comparison of the total bases removed by dialysis and by displacement is given in Table I and shows a rather close agreement, especially for the sodium and potassium. A number of the soils contained coral rock or coral sand, which has caused some disagreement in the calcium and magnesium determined by the two methods. But if these soils are not included the agreement is quite good. The data are sufficient to show that, as Bradfield and Mattson have previously stated, the dialyzable bases of soils are largely present as a part of the colloidal zeolite complex.

TABLE I

Showing Per Cent Zeolite Bases by Dialysis and by Displacement

	Calcium		Magnesium		Sodium		Potassium	
Soil No.	Dial.	Displ.	Dial.	Displ.	Dial.	Displ.	Dial.	Displ.
3	.646	.557	.350	.368	.083	.066	.099	.084
4	.045	.044	.009	.011	.007	.017	.012	.025
5	.228	.254	.338	.428	.172	.145	.056	.043
6	.090	.140	.130	.142	.126	.071	.032	.009
7	.574	.528	.072	.114	.034	.025	.047	.050
8	.214	.319	.009	.021	.027	.029	.013	.012
9	.364	.542	.006	.025	.021	.022	.012	.012
10	.639	.760	.006	.037	.044	.028	.025	.021
11	.150	.117	.013	.009	.029	.021	.015	.012
12	.078	.121	.008	.015	.026	.017	.021	.021
13	.208	.150	.088	.058	.062	.044	.049	.054
14	.131	.092	.069	.044	.028	.032	.027	.042
15	.227	.288	.047	.056	.029	.046	.031	.038
16	.127	.184	.009	.015	.025	.032	.020	.011
17	.313	.364	.051	.169	.034	.049	.030	.051

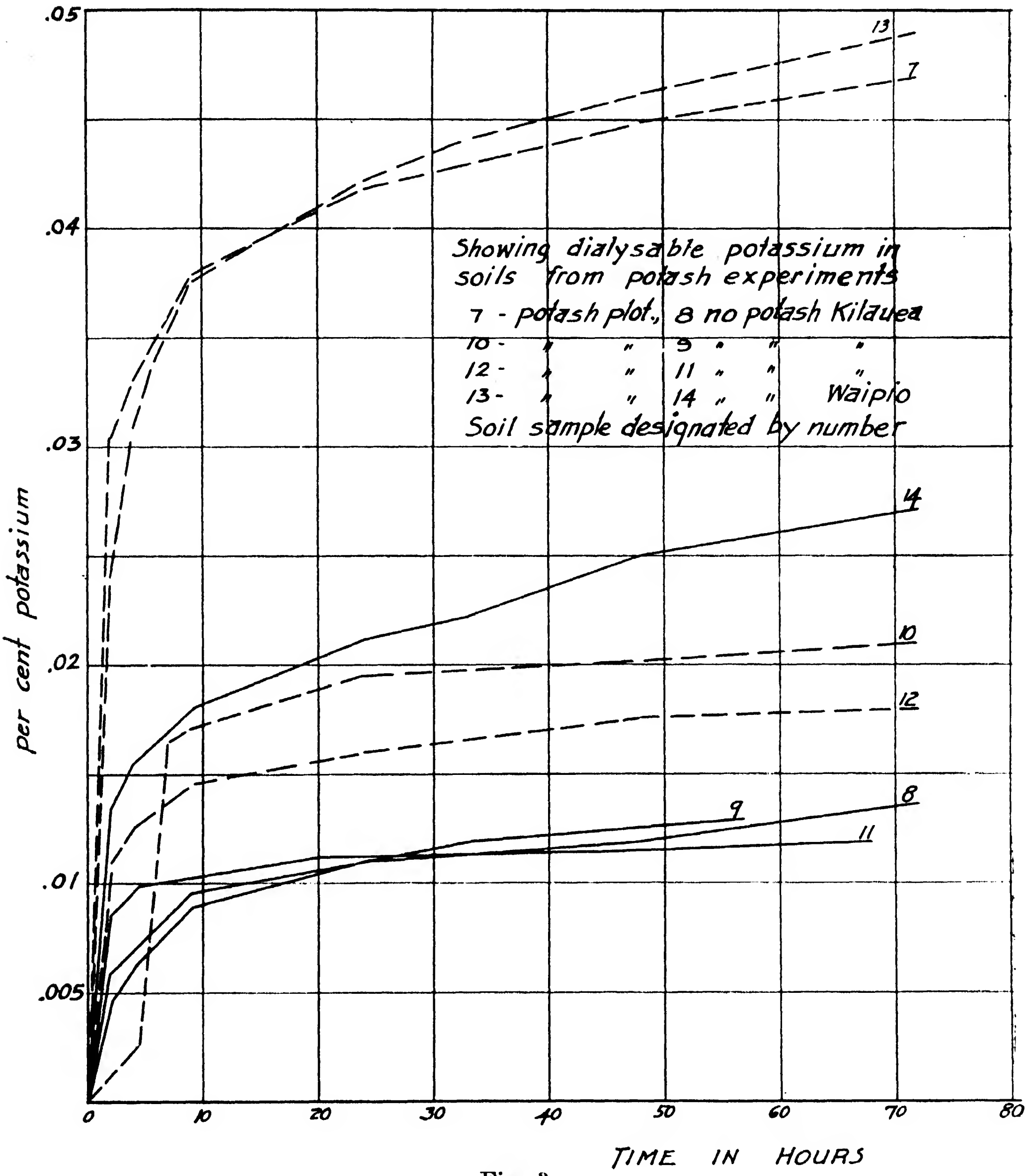

Fig. 3

In Fig. 3 are shown the rates of dialysis and the total amount of dialyzable potassium in the soils from the field experiments at Kilauea and Waipio substation. The potassium, which has been added in the fertilizer, is shown to have been fixed as a dialyzable compound, which is without question the zeolite, and confirms the results we obtained on these same soils by base replacement as well as the interpretations which were made. The conclusion is inevitable that the zeolite potassium present in Kilauea soils is just as active chemically to a replacement reaction, or the process of dialysis, as that in other island soils. Furthermore, the same holds true for the potassium absorbed by the soil after its addition as fertilizer.

Plants absorb inorganic salts only from the soil solution and the absorption is primarily, if not entirely, as ions. That is to say, if sulphate of potash (K_2SO_4) is added to a soil as a fertilizer, this salt will be dissolved in the soil solution and separate or dissociate, in part, as potassium ions $(K)^+$ and sulphate ions $(SO_4)^{--}$, preceding absorption by the plant. The absorption proceeds through the membrane surrounding the absorbing surface of the root, which is semi-permeable and to a degree selective, depending upon the needs of the plant. The phenomenon of potassium absorption, then, is largely one of dialysis. Therefore, it is not surprising that dialysis has been extensively employed in soil solution and plant nutrition studies, because all ions passing a semi-permeable membrane, such as parchment or collodion, are also capable of assimilation by the plant. The rate of dialysis, for difficultly soluble compounds is governed by the rate of hydrolysis and ionization of the compound and, where equilibrium is established at low concentration, the process proceeds very slowly.

If potassium sulphate is not entirely absorbed by the plant within a very short period following fertilization, the potassium ions will be fixed by the soil zeolites, in a form much less soluble than the sulphate. Upon the subsequent availability of this the plant is entirely dependent, otherwise it would be necessary to add soluble potassium fertilizer continuously to supply the needs of the crop. Under natural conditions potassium is present in the soil solution only in small amounts, and usually less than calcium, magnesium or sodium. It is apparent from this that the equilibrium concentration for potassium from zeolite is lower, or that the fixation is greater. Therefore, we cannot expect under normal conditions to find large amounts of potassium in the soil solution at any one time. Our interest, then, is centered upon the soil environment essential for increasing or maintaining the equilibrium concentration of potassium ion from zeolite.

The zeolite anion, with which the potassium is combined in its fixation, is not a soluble ion, being of colloidal dimensions and, therefore, the availability of the fixed potassium will depend upon several factors, notably the presence of other ions in the soil solution. For example, the equilibrium concentration of potassium may be increased by an exchange reaction between zeolite potassium and the base of another salt, which may be added in sufficient amount to disturb the equilibrium of the solution. Such a reaction, however, can only follow a fertilizer application or the addition of salts in the irrigation water. The common ions, on which the solubility of zeolite potassium largely depends, are not the basic ions but rather the acid ions such as nitrate and bicarbonate, which are supplied through the activities of the soil bacteria. Hence one value of active biological life in the soil.

We have shown that the Kilauea soils are well supplied with zeolite potassium, that is, as compared with other island soils. We have further shown this form of potassium to be actively displaced by other bases, readily dialyzable, and readily available, subject to favorable environment. In a separate investigation which we made of the biological activities in Kilauea soils, we obtained much evidence which proves that such activities were reduced to a minimum after the cane "covers in" and the soil temperatures are reduced. It seems fair to assume from these observations that this reduction in the biological life will result in a material lowering in the rate at which the elements will replace those drawn from the soil solu-

tion by the plant, and that what appears to be an ample supply of available potassium during the initial stages of crop growth will prove sorely deficient following the period at which the cane "covers in". That is to say, the potassium, which is fixed by the zeolite, when in contact with the soil solution, soon reaches by hydrolysis a definite equilibrium concentration. If free from the influence of outside factors, especially under Kilauea conditions, where the concentration of the soil solution is very low, the amount of potash in the soil solution will be very small at equilibrium, even where zeolite potassium is ample. This equilibrium concentration will be greatly increased if the soil bacteria are active and supplying the acid ions, nitrate and bicarbonate, which must draw on the zeolite bases for elements with which to combine. Thus the hydrolysis and ionization of the zeolite bases will be increased, as will also their availability. In a similar manner the carbon dioxide secreted by the roots will, in the form of bicarbonate, exert a pull upon the zeolite potassium, but unless root growth is very active the pull will not be sufficient to supply the needs of the aerial portion of the plant.

Potassium availability in Kilauea soils, then, appears to be largely a problem of increasing bacterial activities or stimulating root growth as a means of drawing the zeolite potassium away from the zeolite complex.

Our study of soil electrodialysis was primarily to obtain information on potash availability but, in view of the extensive application which it has found in soil science, we decided to study it more thoroughly while the opportunity permitted. The rectifier, which we used for converting A. C. into D. C., was a home-made apparatus, and, while serving the purpose excellently it required a great deal of attention to keep it in perfect operation. So, in order to compare the efficiency of this rectifier and determine the thoroughness of our dialysis, two Westinghouse* rectigons were obtained, a soil fairly high in all the zeolite bases was selected and was subjected to electrodialysis with a single rectigon, two rectigons in series, and with the aluminum-lead-ammonium-phosphate rectifier. With the latter and with the single rectigon, no resistance was necessary, so the rheostat was used only where the two rectigons were connected in series, and this in order to prevent heating within the dialyzing cell, which will result from using too strong a current. The data obtained by dialyzing under the above conditions are given in Table II and shown graphically in Fig. 4.

* 20 to 30 D. C. volts; 0 to 3 amperes; style 289417A.

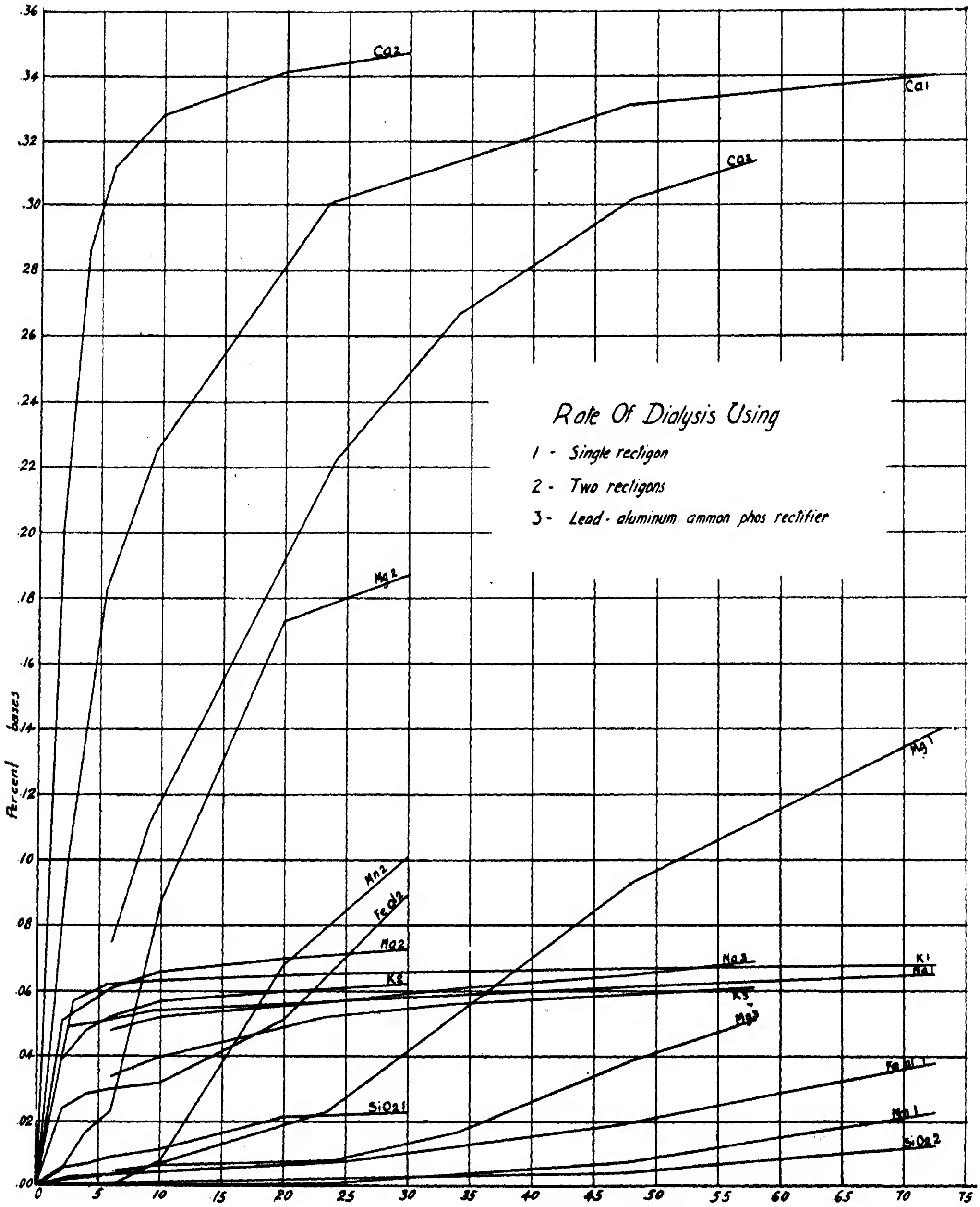
Rate Of Dialysis Using
1 - Single rectigon
2 - Two rectigons
3 - Lead - aluminum ammon phos rectifier
Percent bases
TIME IN HOURS
Ca2
Ca1
Ca3
Mg2
Mg1
Mn2
Fe Al 2
Na2
K2
Na3
K1
Na1
K3
Mg3
Fe Al 1
SiO2 1
Mn 1
SiO2 2
.36
.34
.32
.30
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
.00
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75

Fig. 4

Potassium K					Current *			
1	2	3	Volts	Amperes	Volts	Amperes	Volts	Amper
.0392	.....	.0198	33	.59	..	...	46	.32
.....	.0578	.....	..	...	44	.43	..	...
.0094	.....	.0080	75	.26	..	...	57	.11
.....	.0044	.....	..	...	45	.22	..	...
.0034	.....	.0068	77	.26	..	...	58	.08
.....	.0014	.....	..	...	34	.12	..	...
.0056	.....	.0056	79	.28	..	...	56	.11
.0014	.....	.....	81	.21	..	...	..	...
.....	.0014	.0114	..	...	36	.11	53	.13
.0010	.....	.....	80	.15	..	...	..	...
.....	.....	.0042	..	...	..	...	62	.09
.....	.0026	.0034	..	...	43	.08	60	.08
.....	.....	.0022	..	...	..	...	66	.07
.....	.0010	.....	..	...	44	.07	..	...
.0624	.0686	.0614						

* The voltmeter and ammeter readings were taken the end of each period of dialysis, just before remov dialysate for analysis.

The sodium, potassium and calcium agree quite closely. The dialysis of magnesium was not carried to completion and hence there is less agreement. This soil is an alkaline type and therefore gives up its magnesium very slowly. It is very evident that the lead-aluminum-ammonium-phosphate "set up" gave a D. C. current of required efficiency for the electrodialysis of soils. On the other hand the current supplied is so greatly reduced that dialysis is very slow. The efficiency of conversion, that is A. C. into D. C. also is probably far from perfect and therefore a limiting factor. The application of the single rectigon is limited by low current. By using two rectigons, in series, and adjusting the rheostat just sufficient to control the temperature in the dialyzing cell, dialysis will proceed very rapidly and will be complete in practically twenty-four hours. It will be noted that large amounts of iron, aluminum, manganese and silica, were dissolved from the soil when dialyzed with the two rectigons. This, however, does not appear to influence the zeolite bases or increase the amount of bases, but presents a question as to the effect of electrodialysis upon the absorbing complex of the soil.

Effect of Electrodialysis on the Soil Zeolites

The large amounts of iron, aluminum, and manganese did not make their appearance in the dialysate until the calcium, magnesium, sodium, and potassium were almost completely removed. During the process of dialysis, as the zeolite bases are ionized and pass through the membrane, leaving behind the nondiffusible anion, hydrogen takes the place of the bases in the zeolite complex to form the acid or hydrogen zeolite. Therefore, as dialysis proceeds, the soil within the parchment chamber becomes increasingly acid. This hydrogen zeolite on hydrolysis and ionization, has a solvent effect upon the oxides and hydrates of iron and aluminum in the soil, which then, as ions, move toward the negative pole where, like the magnesium, they are precipitated as hydroxides. While this is the simplest explanation, it was not at all improbable that some of the dialyzable aluminum and silica were being formed by a destruction of the zeolite complex.

In the following table there are given the original reaction and the reaction of the same soils after the bases had been removed by dialysis:

TABLE III

Showing Reaction, pH of Soils Before and After Dialysis

Soil No.	pH Before Dialysis	pH After Dialysis
3	8.0	4.4
5	5.8	3.6
6	5.8	3.7
7	8.0	5.9
8	6.5	4.9
9	7.1	5.7
10	7.7	7.0
11	5.7	5.2
12	5.7	4.5
13	8.1	5.7
14	7.4	5.7
15	6.7	5.4
16	5.9	5.8
17 Pb-Al rectifier	7.9	4.5
17 2 rectigons	7.9	3.8
17 1 rectigon	7.9	4.3

With the exception of one sample, No. 10, which contains a large amount of coral sand, there has been a considerable increase in acidity. All the above determinations were made upon the air-dried soil and in the dialyzed soil it was necessary to remove the soil from the chamber by washing with a stream of distilled water. The whole was then placed in a galvanized pan and allowed to evaporate and dry spontaneously in the air and exposed to sunlight. Knowing that air drying materially affects the reaction of Hawaiian soils, it is possible that the reaction of the soil within the dialyzing cell may have been, and probably was, more acid than indicated by the reaction in the above table. That the soils prepared as above were not completely unsaturated with respect to bases is shown by a comparison of the replaceable hydrogen and replacement capacity of the soils which were determined and calculated to a milliequivalent basis and are given in Tables IV and V.

TABLE IV

Showing Total Acidity, Reaction in pH, Hydrolytic Acidity and Exchange Acidity in Soils Before and After Dialysis, Expressed as Milliequivalent Hydrogen

Soil No.	Reaction pH		Total Acidity		Exchange Acidity		Hydrolytic Acidity	
	Before	After	Before	After	Before	After	Before	After
3	8.0	4.4	none	33.2	none	23.9	none	9.3
5	5.8	3.6	8.9	50.0	.6	38.9	8.3	11.1
6	5.8	3.7	4.0	19.0	.2	12.1	3.8	6.9
7	8.0	5.9	none	11.1	none	1.0	none	10.1
8	6.5	4.9	4.8	17.7	.4	2.9	4.4	14.8
9	7.1	5.7	none	15.4	none	1.4	none	14.0
10	7.7	7.0	none	2.8	none	.6	none	2.2
11	5.7	5.2	8.8	14.0	1.0	.7	7.8	13.3
12	5.7	4.5	8.0	16.0	.6	1.7	7.4	14.3
13	8.1	5.7	none	13.6	none	1.8	none	11.8
14	7.4	5.7	none	13.7	none	2.4	none	11.4
15	6.7	5.4	....	20.1	....	3.1	none	17.0
16	5.9	5.8	18.7	25.6	.2	1.4	18.5	24.2
17 Pb A1 rectigon.	7.9	4.5	none	19.4	none	10.1	none	9.3
17 2 W. rectigons..	7.9	3.8	none	26.7	none	16.3	none	10.4
17 1 W. rectigon...	7.9	4.3	none	23.8	none	13.9	none	9.9

In order to determine the effect of dialysis upon the absorbing complex of the soil, the samples were, after dialysis and drying in the air, carefully examined as to the forms of acidity developed and the state of the replacement capacity of the soil. The so-called exchange acidity was determined by leaching 5 grams of soil in a Gooch crucible with 250 c.c. of neutral N/1 $BaCl_2$ and titrating the leachings with N/10 $Ba(OH)_2$, using phenolpthalein as an indicator. The hydrolytic acidity was determined by leaching 5 grams of soil with 250 c.c. of neutral N/1 $Ba(C_2H_3O_2)_2$ and titrating the leachings with N/10 $Ba(OH)_2$, using the quinhydrone electrode. The results are given in Table IV and shown graphically in Figs. 5 and 6.

In the original soils there is little exchange acidity, the hydrogen being present largely in hydrolytic forms. There is a close relation between soil reaction expressed as pH, and the amount of zeolite hydrogen, as shown by the similarity of the curves in Fig. 5.

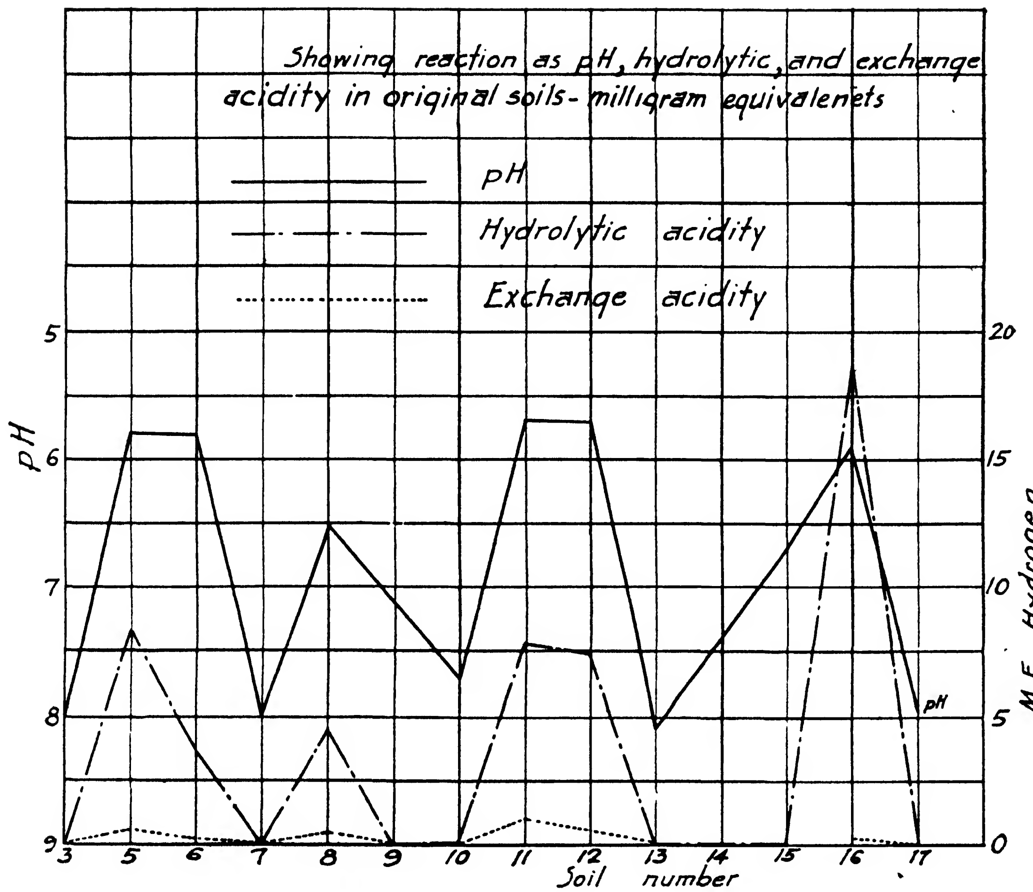

Fig. 5

The effect of dialysis has been to greatly increase both the exchange and hydrolytic acidity. The difference between the effect of dialysis upon the Kilauea soils, as compared to some of the other soil types, is of more than passing interest. In no case has a Kilauea soil shown more than a very slight fixation of hydrogen to form the so-called exchange acidity. This suggests a strong fixing power of the soil zeolites for hydrogen. A low solubility of zeolite potassium in 1 per cent citric acid likewise gave evidence of a strong fixing power in Kilauea soils. In work upon soil acidity it has been shown that the salt of a weak acid, such as barium acetate for example, will have a greater replacing power for soil acidity than the salt of a strong acid, such as barium chloride. The hydrogen displaced by the latter is referred to as exchange acidity and will include the acidity due to aluminum salts as well as a small amount of fixed hydrogen ions. Leaching an acid soil with a reasonable amount of a neutral solution of an acetate will give a complete and rapid replacement of all active hydrogen. In the data shown in Table IV and Figs. 5 and 6, total acidity represents the total amount of hydrogen ions present in replaceable forms and determined by displacement with barium acetate solution. The hydrolytic acidity is taken as the amount of hydrogen not displaced by 250 c.c. of N/1 barium chloride, or the difference between the total replaceable acidity and the exchange acidity. A very large amount of replaceable

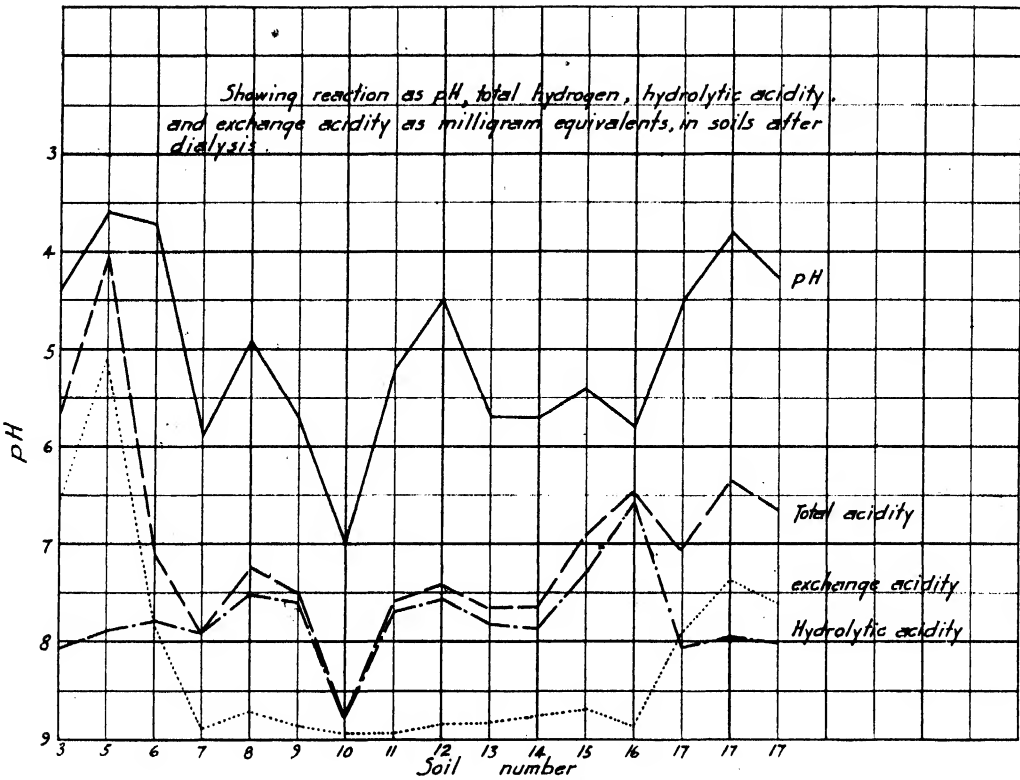

Fig. 6

hydrogen in the barium chloride leachings would indicate that the acidity is more active. In other words, that the hydrogen ion is more loosely held and therefore will hydrolyze and ionize more rapidly and to a greater concentration at equilibrium. On this basis we are led to suspect again a difference in the nature of the zeolites present in Kilauea soils. Their original hydrogen is present almost entirely as hydrolytic acidity, as is also the additional amounts of hydrogen absorbed during dialysis. The Waipio, Pahala, and Hilo soils, too, show a low fixation of hydrogen as exchange acidity. There is in this property much of interest. Several of the soils used in this series are characterized by unusually large amounts of zeolite magnesium, and it will be noted that in every case these types during dialysis fixed their hydrogen loosely, or in the form of the so-called exchange acidity. And vice versa, in every case where the soil was low in zeolite magnesium the exchange acidity was low, in fact almost negligible, and the hydrogen was fixed strongly and largely as the so-called hydrolytic acidity. In other words, the equilibrium concentration of hydrogen ions is greater in the dialyzed soils, which were originally high in zeolite magnesium. This property of the magnesium zeolites is shown in Fig. 7.

The question of the presence of iron, aluminum, and manganese in soils, as exchangeable components of the absorbing complex, is still more or less an unsettled issue. On the other hand, it is definitely known that the nondiffusible "acidoid" anion of the absorbing complex is largely an alumino-silicious complex. The appearance of these elements in such large amounts in the products of dialysis could easily be taken as an indication of the destruction of the zeolite, which is

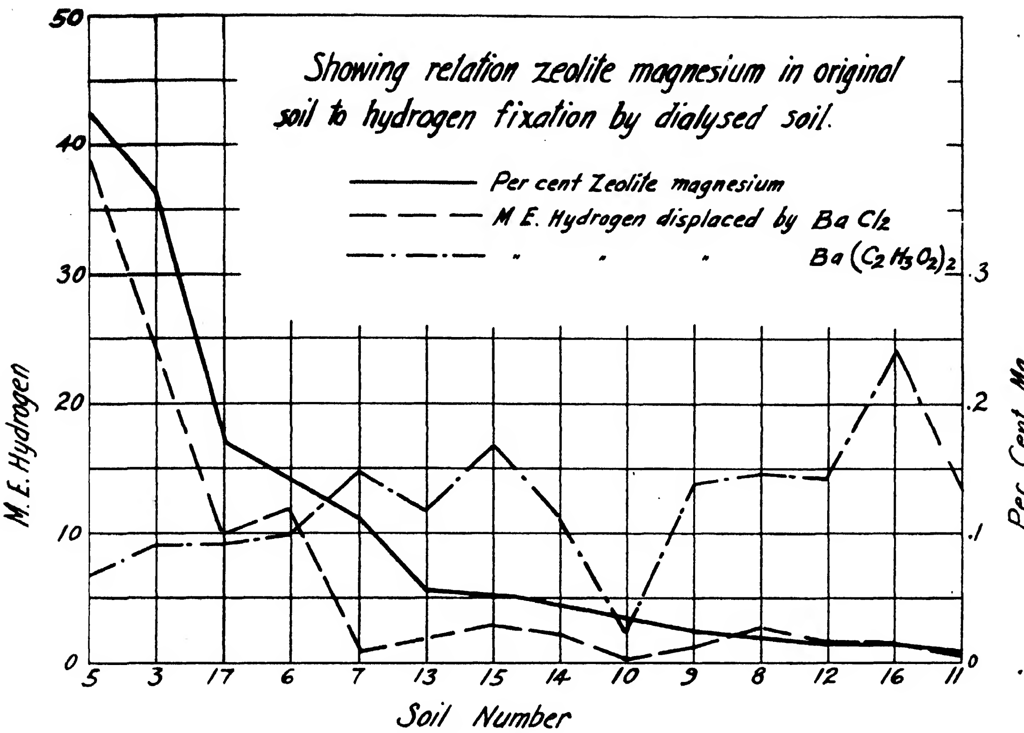

Fig. 7

known to be more or less unstable under certain conditions. A destruction of zeolite would materially reduce the exchange properties of the soil and thereby greatly affect its exchange capacity. So, in view of the fact that only negligible amounts of aluminum, manganese, or iron have appeared in the displaced solutions of our soils, we suspected a destruction of the zeolite complex, at least in part.

To determine this, the exchange capacity of the soil, before and after being subjected to dialysis, was determined. The results are given in Table V.

TABLE V

Showing Exchange Capacity of Soils Before and After Dialysis—Results Expressed in Terms of Milliequivalents per 100 Grams

Soil No.	M. E. Before Dialysis	M. E. After Dialysis
3	62.8	62.2
5	63.5	61.9
6	20.9	25.1
7	23.2	21.1
8	19.1	20.6
9	29.4	27.1
10	22.8	21.5
11	16.7	16.9
12	16.4	17.3
13	18.4	16.7
14	16.8	15.7
15	32.4	35.9
16	30.8	29.5
17 Pb-Al-rectifier	31.6	31.0
17 2 W. rectigons	31.6	32.0
17 1 W. rectigon	31.6	31.4

It is evident from the above that the iron, aluminum, and manganese were not derived from the zeolite, but rather were dissolved by the action of the hydrogen ion upon the hydrates and oxides present in the soil. And from the above one would be inclined to question the presence of these elements, iron as ferric, in replaceable forms in soils, especially on observing the results obtained on soil 17. Using the strongest current, two rectigons, which brought into solution .022 per cent silica, .089 per cent iron and aluminum oxides, and .1019 per cent manganese oxide, there was absolutely no change whatever in the exchange capacity of the zeolite in this soil. Since this stability of the zeolite complex was shown in all the soils subjected to electrodialysis, we are forced to recognize a highly stable exchange colloid in our soils.

Summary

The effect of electrodialysis upon Hawaiian soils has been studied from the standpoint of its relation to the availability of calcium, magnesium, potassium and sodium naturally present in the soil and the potassium added with the fertilizer.

The stability of the colloidal soil zeolites, as affected by electrodialysis, has also been given some attention.

The amounts of calcium, magnesium, potassium and sodium removed by electrodialysis are quite definite and agree with that determined as exchange bases by displacement with salt solutions.

Potassium added as fertilizer is fixed by the soil colloids in a readily dialyzable form.

An apparatus and method have been described which, when using two Westinghouse rectigons in series, and controlling the temperature in the dialyzing cell by means of a rheostat, a rapid and accurate dialysis of the soil may be made.

It has been shown that on subjecting the soil to electrodialysis by the above method, there will be a notable solubility effect toward iron, aluminum and manganese present in the soil as oxides or hydrates, but that this is not associated with any destruction of the absorbing complex of the soil.

There is some evidence given that the fixing power of the zeolite for hydrogen is in some manner influenced by the magnesium content which it originally possessed. Zeolites, which were high in magnesium, appear to possess the property of fixing hydrogen in more easily replaceable forms, namely, the so-called exchange acidity.

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Some Chemical Reminiscences*

By Dr. L. L. Van Slyke

First, I am going to say something about the pioneer days of chemistry in Hawaii. In 1884, I was invited to come to Honolulu to teach in Oahu College at Punahou, and to serve as chemist for the Hawaiian government, a position then newly created. The Rev. Dr. C. M. Hyde, secretary of the Board of Trustees of Oahu College, wrote to one of the professors of the University of Michigan, asking that he be put in touch with some young man who would consider a position in Honolulu as teacher of chemistry. This letter was turned over to Dr. Prescott, head of the department of chemistry, in which I was an instructor. Dr. Prescott handed me the letter with an enigmatic smile and the remark that I might be interested in the proposition.

After reading the letter, my first reaction was geographical—Where is Honolulu? On recalling my early school training, I decided that it might be in the West Indies, or, perhaps, in the remote and little-known Sandwich Islands. An atlas confirmed the latter supposition. As a result of ensuing correspondence, it was finally arranged that I should begin work in September, 1885.

The little building on Punahou campus, known as Bishop Hall of Science, had just been completed and awaited my arrival for proper equipment. Some months before, I had ordered chemicals and apparatus, largely from Germany, and these arrived in November. Among these supplies was a Westphal balance, which, I learn, is still doing good service. The source of laboratory heat was a special gasoline burner and a gasoline stove for student use. I never ceased to be nervous over the possibility of a blow-up, but we were evidently under the protection of a special providence.

Bishop Hall of Science made possible for the first time the use of laboratory methods in teaching chemistry in these Islands. There were many interesting, and some amusing, experiences but time does not permit details in regard to the teaching work.

You may be interested to know what were some of the kinds of work which the government called upon its chemist to do. The first case was a sample of "moonshine" liquor, which some Chinaman had been caught making. You will notice that bootlegging in Hawaii is not an exclusive development of recent times. The Marshal of the Kingdom, who was the general grand sheriff of the Islands, brought the sample. He still survives in the person of General J. H. Soper, who, after he ceased to be Kalakaua's marshal, helped make history in the troubled days of the birth of the Republic of Hawaii. Analysis showed the sample of "moonshine" to contain 40 per cent of alcohol.

His Majesty King Kalakaua was interested, from time to time, in having various materials examined. The first sample was a pretty crystal of iron pyrites.

* **Address delivered before the Hawaiian section of the American Chemical Society, Honolulu, May 16, 1929.**

He was undoubtedly disappointed to learn that his find was not a high-grade nugget of pure gold. The chemist did not include in his official report the statement that the common name of the material was "fool's gold".

Another sample was a piece of anthracite coal, which was picked up on Kalakaua's cattle ranch, located on the present site of Schofield Barracks. It was easy to identify the material, but not so easy to tell by what accident it came to be where it was found.

His Majesty must have been disappointed and discouraged in his earnest efforts to get scientific help in developing the mineral resources of his kingdom, particularly in relation to mines of gold and coal. I presume he came to regard the government chemist as an unprofitable servant.

In consultation with two of the trustees of Oahu College, Sanford B. Dole, then practicing law here, later Hawaii's "Grand Old Man," and A. F. Judd, Chief Justice of the Supreme Court of Hawaii, father of Lawrence M. Judd, Hawaii's next governor (who had not then been born), it was decided that a chemical survey of the various sources of domestic water supply of Honolulu should be made. This was carried out during the months of February, March, and April, 1886; and the report of the investigation was published in the biennial report of the Minister of the Interior to the Legislative Assembly of 1886 in the thirteenth year of the reign of His Majesty Kalakaua. Over twenty samples of water were collected, with the assistance of the superintendent of the city water works, Mr. Chas. B. Wilson, who later gained notoriety as an evil genius behind the throne in the reign of Queen Liliuokalani.

The main water storage was a reservoir at Luakaha, up Nuuanu Valley, and a filtering reservoir lower down. This was supplemented by Kapena Spring and, in addition, several artesian wells located at Waikiki, Pawaa, Thomas Square, Palace Square and Makiki. These analyses were the first made of Honolulu waters. While the methods of water analysis in 1886 were not as satisfactory as those of today, and the methods of bacteriological analysis of water had not been developed, the results were, in general, fairly reliable in identifying really dangerous water. The results of this first chemical survey of Honolulu's domestic water supplies indicated that the water was in a good to fair sanitary condition, with the exception of that of the Thomas Square artesian well, which was seriously contaminated with impure surface water. This abnormal condition led the superintendent of water works to do some investigating and he discovered a leakage of water from an abandoned concrete reservoir, located just below Makiki Valley, the pipes of which had not been disconnected from the Thomas Square district. After the water of the Makiki reservoir was completely shut out, a later examination showed a normal condition. One other point of interest was the difference in softness between the water of the artesian well at Waikiki and the other wells in the city. The Waikiki water was much softer, due to the presence of sodium bicarbonate.

I will refer to only one other form of chemical activity in Hawaii in those days, my relation to the agriculture of the Islands. Some of the sugar planters began to be interested in the possibilities of getting some help from the application of chemical knowledge to a study of their problems. Only one attempt had

been made previous to 1885 to get such help. Claus Spreckels was at that time a commanding figure in the sugar industry. He had in his employ in his San Francisco refinery a German chemist, who had become a victim of fondness for alcohol. This chemist was transferred, as a reform measure, to the Spreckels plantation on Maui, but was so rarely sober that he was finally turned loose on the community as a consulting analyst. One of the planters related an experience with this agricultural chemist, who visited his plantation, took samples of soil and reported the results of analysis the next day, recommending a fertilizer formula, for which a generous fee was charged. I never had the privilege of meeting this fellow chemist. He was the first representative of agricultural chemistry in Hawaii, but we would hesitate to regard him as the first representative agricultural chemist.

Soil analysis was then in a very elementary stage and I was providentially saved by my inexperience, modesty, and lack of equipment from wasting time in analyzing soils under the then existing conditions. However, I became the first teacher of agricultural chemistry in Hawaii, without intending to. Henry M. Whitney, the postmaster general, was also editor and, I think, founder of the *Planters' Monthly*. He persuaded me to write a series of articles on agricultural chemistry. I know that the articles were reliable because they were made up from Johnson's *How Plants Feed* and *How Crops Grow*, Ville's *Manures* and some other standard books of the time, which I had fortunately included in my personal library, which I brought with me to the Islands. This was the first course in agricultural chemistry to be taught here. For a young man, I believe that I was reasonably conservative, and I have the present satisfaction of believing that the course of instruction did not result in any serious damage to the progress of agriculture.

A few years later, after I had left the Islands, Mr. Whitney wrote me of the purpose of the Planters' Association to secure a chemist and asked me to suggest some one. I referred him to Dr. Wiley, chief of the Bureau of Chemistry, of the United States Department of Agriculture. This suggestion resulted in the engagement of Dr. Maxwell and the beginning of the gradual development of the Hawaiian Sugar Planters' Experiment Station.

The Bishop Hall of Science may properly be regarded as the pioneer chemical laboratory in Hawaii. To what extent this institution developed a chemical trend of thinking and was influential in starting the train of circumstances, which has resulted, in the couse of forty years, in the splendid research organizations which we find here today, who can say? The chemists of Hawaii have made very notable contributions, not only to the solution of many of the problems peculiar to the local conditions, but also substantial, valuable additions to the knowledge of agricultural chemistry in a broader way.

The history of the pioneer days of chemistry in Hawaii would not be complete without the mention of Dr. Stangenwald. He was a physician, of German birth and training, and for many years one of the most successful practitioners here. He had his hobby in chemistry and accumulated physical and chemical apparatus and supplies in great variety and quantity. He kept his chemical work and his purposes completely to himself. Nobody knew what he was doing or

trying to do, and so there were numerous surmises. One guess was that he was trying to chase that old will-o'-the-wisp, the Philosopher's Stone, in order to transmute common metals into gold. Nobody knew; everybody wondered and guessed. He died without ever taking anyone into his confidence. I met Dr. Stangenwald once while I was here, not long before I left the Islands in 1888. He was a man of attractive personality. On this one occasion he showed no inclination to talk about chemistry in general or in particular. When I was visiting here in 1915, I was asked by his niece, Mrs. Nellie Waterhouse Wood, one of my Punahou pupils, who had inherited Dr. Stangenwald's property, to look over the library and laboratory equipment, occupying several rooms, in order to advise her what to do with it all. The chemical part of the library consisted of German and French publications of the day, furnishing no clue as to his line of work. The apparatus, chemical and physical, consisted of many kinds in large quantities, electrical apparatus, various kinds of furnaces, etc. Dr. Dillingham tells me that the University acquired much of the collection and he can tell you more about its details than any one else. Dr. Stangenwald was the mystery man of his day in Honolulu. Whether he could have contributed anything to chemical knowledge, if he would, no one can ever know.

The far-reaching changes that have taken place in Hawaii in the last forty years in the application of chemistry to Island problems, mostly agricultural, are typical of the changes that have come in every phase of life here. Then the total population of the Islands was 80,000 and of Honolulu 20,000. Punahou was in the remote outskirts of the city. The region right here where the University is located was an uncultivated, if not a howling, wilderness, accessible only by bridle paths.

There were traffic problems even then. At night every vehicle had to carry a light. The aristocratic had carriage lamps; the plain citizen hung an oil lantern to the front or rear axle of the vehicle. Saddle horses were not required to carry tail lights. Otherwise the streets were not illuminated.

Salaries have changed also. As an instructor in the University of Michigan, I received $600 a year. Full professors there received $2000. When, therefore, I received an offer of $2000 to come to Honolulu, it looked like a princely income. Toward the end of the three-year term of service, for which I had contracted, I began to feel strongly the isolation from contact with fellow chemists. I decided to return East.

The school year of 1888-9, I spent in teaching at the University of Michigan and then carried out a long-cherished plan of spending a year in study with Dr. Ira Remsen at Johns Hopkins University. During my year in Baltimore, I visited Washington and there met for the first time Dr. Harvey W. Wiley, chief chemist of the United States Department of Agriculture.

I want to tell you something of these two men, especially as I came to know them by personal contact. Remsen and Wiley were pioneer leaders in the chemical activities of America. One was the ideal teacher and research worker in pure chemistry; the other was the leader in chemistry applied to agriculture and to pure food control. Each exercised a profound, lasting and helpful influence on the development of chemistry in its pure and applied phases. Remsen was born and

educated in New York City. Wiley was a product of the middle-west environment. Both studied medicine and received the degree of M. D. Remsen was a teacher a large part of his life; Wiley, for several years. They were contemporary, Wiley having been born in 1844 and Remsen in 1846.

In his medical course, Remsen was deeply impressed with the superficial knowledge of chemistry acquired by medical students and of the slight value of such meager knowledge in the practice of medicine. He had, however, acquired enough of a taste of chemistry to lead him to decide that he did not want to practice medicine, but that he did want to learn something about chemistry. He used to say that about the only thing he retained in memory from his first course in chemistry was the statement made by the professor in the medical college that old shirts could be changed into sugar. He felt that chemistry was a wonderful science, about which he knew nothing but wanted to learn.

At that time (1867), it was necessary to go to Europe for an adequate training in chemistry. Remsen first went to Munich to study in Liebig's laboratory, where, under Volhard, he gained his first systematic training in methods of analysis. Liebig himself had given up instruction of students. Remsen became particularly interested in organic chemistry and so went from Munich to Goettingen, at Wöhler's suggestion, to begin research under Fittig. After studying for three years in Germany, he gained the degree of Ph. D. in 1870. The two years following he served as Fittig's assistant at Tübingen. There he began the study of aromatic sulfonic acids and their derivatives, a field of research that held his attention throughout his life.

Returning to the United States, Remsen became professor of chemistry and physics in Williams College. It was a year before he could get a laboratory equipped for his own research work. It sounds strange in this day to learn that he worked in an environment not only unsympathetic but even hostile to experimental science. He, however, succeeded where others had failed. Realizing the need of better methods of teaching chemistry, he purposely concentrated his attention on the art of imparting knowledge. Remsen attracted attention, while at Williams College, by the publication of early research work, and especially by the publication of his *Theoretical Chemistry*, which brought together, in an unified whole, important fundamental principles of chemistry and made clear their relationships in a simple and attractive way.

When President Gilman, in carrying out his ideal of establishing a university based on scholarship and research, looked about for a man to head a department of chemistry at Johns Hopkins University, his choice logically fell on Ira Remsen, who began his epoch-making work there in 1876. In an incredibly short time, Johns Hopkins became the mecca of young men desiring the best available training in chemistry, for both teaching and research. In the course of ten years, Johns Hopkins Ph. D.'s in chemistry were filling many important teaching and research positions in American colleges and universities. Through his work as teacher, his leadership in research, his authorship of model text-books and his editorship of *The American Chemical Journal*, Remsen was easily, for a generation, the greatest force in America in promoting chemical knowledge and research of the highest quality. In no small degree must we attribute to Remsen's initial

influence the powerful impetus which chemical research in America has attained today. I have given this brief survey as a preliminary to what I have to say about my personal contact with Ira Remsen.

As I have already said, I went, one year after leaving Hawaii, to spend the college year of 1889-90 in study with Dr. Remsen, it being my intention at that time to devote my life to the teaching of chemisry. It is somewhat aside from chemistry, but it may be of interest, in passing, to say that I carried to President Gilman a letter of introduction from Judge Lawrence McCully, one of the associate justices of the Supreme Court of Hawaii, and a classmate of President Gilman's at Yale. Incidentally, I may add that the next governor of Hawaii was named after Lawrence McCully.

I attended all of the lectures which Remsen gave, both elementary and advanced, inorganic and organic. He was, in every way, an ideal teacher. The class room teaching was by lecture. The illustrative class room experiments, performed during lectures, were perfect in every detail and served as real factors in the teaching process. His choice, finished phraseology, his ease, smoothness and fluency, his simplicity of expression, his clarity of reasoning, his vividness of description, his occasional flash of pertinent wit, all combined to give his lectures an indescribable charm and a feeling of intellectual satisfaction to the listener. I always felt as if I were in the presence of a master mind.

It was a special privilege to hear him speak on the history of chemistry. He had come into close personal contact with many of the pioneer men who had developed modern chemistry. He gave me the feeling of knowing the men personally myself, as he told of Wöhler, Liebig, von Baeyer, Wislicenus, Bunsen and others. He made their personalities vivid and fascinating. In these lectures, there were mingled with science a delightful philosophy and a keen sense of humor.

Each week there was a journal meeting for graduate students, in which Remsen reviewed with his characteristic analytical clarity the articles of special interest. Individual articles were also assigned to the students for review in practice.

At one of these journal meetings, in going over a pile of journals, he picked up a small, thin, insignificant-looking pamphlet. He said, "This is the last number of the *Journal of the American Chemical Society*. It hasn't a single article in it of the slightest value. Under its name, it is a disgrace to America, as the presumable representative of this country," and he slammed it down on the table with an expression and gesture of supreme contempt. His feeling was justified at the time. It was not long after, however, before some vigorous young men put themselves at the head of the society and began energetic work to develop it into the powerful organization which it has become. About twelve years after this, Remsen, became president of the American Chemical Society. Some years later, when his duties as president of Johns Hopkins University absorbed his entire time, he arranged to have his *American Chemical Journal* combined with the *Journal of the American Chemical Society*.

"Remsen's Journal," as it was usually called by chemists, was started in 1879, as a matter of necessity, because there was no journal in America to handle research

papers in chemistry, and for several years he had been compelled to publish his articles in German journals. *The American Chemical Journal* became one of the recognized valuable chemical publications of all countries. During its extire existence it maintained a high standard. Dr. Remsen was very considerate in publishing contributions from his former students. He published several of mine relating to the chemical phases of cheese ripening. Gradually, the work ran more and more into practical application to cheese making. Finally, he sent a paper back, saying that its character was such that he felt that it did not belong in his journal and he had been in doubt about some of those he had already published. I wrote him, saying that while I regretted his decision, I appreciated his point of view and was grateful to him for having been previously so generous. At once, rather to my surprise, came back from him a gracious letter, in which he said that he wanted to thank me for the truly Christian spirit which I had shown in the situation. After telling me about the purpose of his journal and his trials as editor, he added that his life as editor would have been a much happier one if all who had had papers refused by him had shown the same spirit of sympathetic understanding I had shown instead of bitterly assailing him as a crank.

One of the most delightful personal contacts that the graduate students had with Remsen was in his daily visits in the advance laboratory, located next to his office. He stopped at each desk and talked with the student about the work under way. As I was several years older than the other students, being 30 (Remsen himself was then 43) and as I had had some teaching experience, he often talked with me about other topics than the laboratory work I was engaged in. On one occasion he told me how he came to write his first book on organic chemistry. After taking several courses of lectures in Germany, the subject was simply a chaos of a multitude of unrelated facts. He had a faint glimmering of insight, just enough to lead him to believe that somehow and somewhere there was some kind of a system, but for a time it was extremely vague. He groped and studied, largely in faith, for a long time. Finally, he began to see increasing glimmerings of light, and, gradually, true relations, previously only suspected, appeared. He realized that other students of organic chemistry must be in the same hazy state of mind that had been his. To help others and because there was no other book in the field, treating the subject in the same way, he published his book, *The Chemistry of the Carbon Compounds, An Introduction to the Study of Organic Chemistry.* Although I had had an extended course of lectures in organic chemistry in 1882, I never really knew the subject, until a few years later I read Remsen's book. His first book, *The Principles of Theoretical Chemistry, with Special Reference to the Constitution of Chemical Compounds,* was worked out by sheer force of persistent, personal, intellectual application, in order, primarily, that he himself might have a clear insight.

I will touch upon only one more incident. Among Remsen's students, in 1877-79, was a young German by the name of Constantine Fahlberg, who was working, under Remsen's direction, on the oxidation of ortho-toluene-sulfonamide. Fahlberg accidentally spilled on his working desk one day some of the compound with which he was working. In cleaning it up, he got a trace on his hands. Later, happening to bring his hand in contact with his lips, he discovered

that the substance was intensely sweet. Remsen demonstrated the structure of the compound and called it benzoic sulfinide. After leaving the University, Fahlberg made a personal commercial exploitation of the substance under the name of *Saccharin,* obtaining patents in the United States and abroad, without consulting Remsen. The production of *Saccharin* on an industrial scale was carried on by Fahlberg in Germany. This patenting and monopolistic commercialization of the results of some of his own work was a source of intense chagrin to Remsen, who was opposed, on principle, to the patenting, for private profit, of any result of university research work. I do not know that he ever made any statement for publication about the matter, but he spoke his mind freely to some of his students. What I heard about it came from student talk and was evidently handed down from previous years.

I will close this very imperfect sketch by saying that no earnest student could come in contact with Remsen without being profoundly influenced and helped. It was the most satisfying and profitable year I ever spent as a student. I learned a great deal of chemistry, but I gained even more outside of chemistry—I gained an intellectual stimulation and broadening, which, in the course of forty years, has not ceased to exercise a beneficial effect.

The last time I met Dr. Remsen was in 1907, when he gave the commencement address at the University of Michigan, at which time my son Donald was given his doctorate. Remsen's address was a memorable defense of science against the charge, which some unscientific, distinguished philosophers had been making, that science had become bankrupt. I was privileged to have a short chat with him after the address. He never failed to show a cordial interest in any one who had studied with him.

At the close of my year at Johns Hopkins, it was my hope to obtain a position to teach chemistry. Before a satisfactory position offered, I received an invitation from Dr. Peter Collier, director of the New York State Agricultural Experiment Station at Geneva, to visit the station with reference to considering the position of chemist there. When I received the invitation, I wondered what an agricultural experiment station might be—what it was for and what it was like. I investigated, saw that it offered an opportunity for real research work, was offered the place and accepted it. My previous agricultural education had consisted of the reading necessary for the preparation of the elementary articles on agricultural chemistry that I had written here for the *Planters' Monthly.*

I began my work at the Geneva station July 12, 1890. One month later I went to Washington to represent the station at the annual meeting of the Association of Official Agricultural Chemists, which was, I think, its ninth meeting. There I came into contact with Dr. Wiley again, only a few months after I had met him for the first time, when I had not the remotest idea of becoming an agricultural chemist. From that time on, I was in more or less intimate relations with him, especially through activity in the A. O. A. C., an organization with whose work you are all familiar. I know of no organization anywhere which has accomplished so much really substantial work for the promotion of agricultural chemistry as has the A. O. A. C. For the organization of the association, Dr. Wiley was primarily responsible. For forty years, his was the guiding hand and his the

directing mind that gave to the association consistent purpose and marvelous growth in usefulness. For most of that time he was the secretary and, in reality, the chief executive. Since 1912, Dr. Wiley has been the honorary president. He has never missed a meeting since the beginning of the organization.

A brief outline of Dr. Wiley's activities will be in order here. Born October 18, 1844, at Kent, Indiana, he graduated as A. B. at Hanover College in 1867. He taught Latin and Greek in Butler College, Indianapolis, for two years and science one year in the Indianapolis High School. Meanwhile he was studying medicine in the Indiana Medical College at Indianapolis and took the degree of M. D. in 1871. Deciding that he did not want to practice medicine, but did want to teach chemistry, he went to Harvard University for two years, getting the B. S. degree. He then became professor of chemistry first in Butler and then in Hanover College. He was a pioneer in America in the laboratory method of teaching chemistry. In 1874, Wiley was called to be professor of chemistry in Purdue University and the state chemist of Indiana.

In 1876, Dr. Wiley prepared the first college exhibit of chemical industry made in the United States. It was in connection with the Centennial Exhibition at Philadelphia. He had his students prepare 100 crystallized inorganic compounds. Organic chemistry was not represented, because it was just getting born in the United States under Remsen.

In 1883, Wiley was called to become chief chemist of the United States Department of Agriculture. When I first visited him in Washington in 1890, he had rather ordinary laboratory facilities and not many assistant chemists. In 1912, when he retired, the work had grown into a government bureau and employed over 300 chemists, covering many different lines of work, both routine and research. In addition to the force of chemists in Washington, there were several branch laboratories in different parts of the United States to assist in enforcing the Pure Food and Drug Law.

It is generally conceded that Dr. Wiley's greatest and most useful work was making possible the Pure Food and Drug Act, one of the most beneficent statutes on record, for to him more than any other one man was due its enactment and, during the initial period, its successful enforcement. Only those who had an intimate knowledge of the inside history preceding the enactment can appreciate the difficulties encountered. As one of Wiley's very minor associates, I saw something of these difficulties. In the passage of the law, the politicians were determined to have its enforcement placed in the hands of a political appointee, which would have endangered its success. Wiley was desirous that it should be placed in the hands of his department and, by some miracle, he succeeded in winning his point.

The fight was not finished even after the bill became law—in fact it was only begun. Manufacturers of food and drug products contested many cases bitterly in the courts, in order to modify in their favor some of the legal definitions that had been adopted for pure food and drug products. One of the best known of these disputes related to the use of preservatives, especially sodium benzoate and *Saccharin*. In order to prove his claim that these materials, as used, were injurious to the human body, Wiley undertook a series of experiments, in which he

tested physiologically the effects of these compounds on several vigorous young men, who became known as the "poison squad". The results of his experiments upheld his contention, but his methods were so vigorously criticized, that the president was persuaded to appoint a special commission to repeat Wiley's experiments. At the head of the commission was Ira Remsen. After many months of careful work, this commission reported that these preservatives were harmless when not used in excess of certain amounts. The commission, in carrying out its experiments, distributed the preservative uniformly through the mass of food eaten. Dr. Wiley, in his experiments, administered the preservatives in capsules. This method was criticized on the ground that, when the capsule dissolved in the stomach, its contents were set free in concentrated form and, before distribution could take place, acted directly on a portion of the stomach wall, producing the uncomfortable symptoms which Dr. Wiley found in his experiments, but which the commission did not find by its method of experiment, even when the same amount of preservative was used. Dr. Wiley's work was criticized also on the ground of using larger amounts in some of his experiments than were employed in commercial practice. Dr. Wiley never accepted the results of the commission's work, but the law was modified to permit certain amounts of certain preservatives. A further contention which Dr. Wiley put forward against the use of preservatives was that they were not needed at all, provided the materials were sound and sterilization complete, and the truth of his contention he established. If Dr. Wiley's zeal for public interest led him at first to advocate some standards that were more drastic than necessary, his purpose must be commended. His integrity was never under suspicion.

Each year at the meeting of the A. O. A. C., Dr. Wiley was called on to make an informal address on some topic of his own choosing—it was generally something particularly pertinent at the time. These talks were looked forward to as the most interesting feature of the meeting and they were never disappointing. He spoke without notes and, to all appearances, extemporaneously. The last time I heard him give one of these unique talks was in October, 1927, when he had just passed his 83d birthday. It was fully up to his high standard of former years. His mind was just as alert as ever, his expression as fluent, his logic as clear, his wit as keen; and the whole talk was as illuminating and stimulating and enjoyable as any he ever gave us. One of Dr. Wiley's attractive qualities is his wit, which is always bubbling over spontaneously. I recall an instance when the subject of starch determination was under discussion at one of the meetings of the A. O. A. C. One of the methods suggested was the digestion of starch by the use of saliva. Dr. Wiley remarked that the method gave excellent results, but that some objected to it on the ground that it was not "nice". He then added, " 'Tis true, 'tis spitty, and 'spitty 'tis, 'tis true."

After his retirement, a banquet has been held in Dr. Wiley's honor each year during the meetings of the A. O. A. C. by the older members of the organization. I shall not forget the occasion of this kind when I was last present, a year and a half ago. These were occasions of intimate personal reminiscences, as we sat together. Dr. Wiley was at his best. For two hours he held our closest attention. He told us of some of his personal contacts with great men at home and abroad in

his inimitable way of thrilling interest. He talked of the development of chemistry in America and, finally, of the inner history of the enactment and enforcement of the Pure Food and Drug Law. At the close of this confidential family talk, I remarked to him that the facts which he had been telling us ought to be given a permanent record. He said he was working on an autobiography, which he hoped to finish before he was called from his labors. He said that he proposed to tell facts as they actually were and not as some had erroneously been led to believe. I can assure you that the book will be well worth reading. It will surely be informing. It will also certainly be the center of some stirring controversy.

It has been an interesting time to be a student of chemistry during the past fifty years. Much the greater part of the body of our chemical knowledge has been added during this period. The growth of chemical activity in America has been simply amazing—indeed, we can not fully comprehend it. Chemistry used to be studied in college as part of a liberal education and not enough was acquired to do any harm. Medical students were required to get a smattering, but not enough to do them any good. I knew a young medical student at Ann Arbor who said that he wanted to learn chemistry so that he could synthesize quinine. Most of those who took more than elementary inorganic chemistry intended to teach chemistry or become analytical or industrial chemists or pharmacists. A few under Remsen were beginning to get a vision of the possibilities of research. I do not remember ever to have heard the word research applied to chemical investigation, when I was a student. The expression then used was "original investigation".

The period of organic chemistry had then set in and continued to absorb most of the activity of American research students for years. Early in the nineties we began to hear of new developments abroad in physical chemistry and this field attracted an increasing amount of attention from Americans studying in Europe. Later it became very prominent in American research, especially in its applications to colloids. Since the beginning of the present century, interest has centered in ever-increasing intensity about biochemistry, which is, of course, simply the application of chemistry, whether inorganic, organic, or physical, to the study of living organisms and processes. With the passage of the Hatch Act by the Congress of the United States and the establishment of agricultural experiment stations in every state, there was a sudden unforseen demand for chemists for research work. It is a marvel not that, in such an emergency, there were some poorly trained and inefficient men brought into the service, but that there were so many capable, strong men, among whom may be mentioned Atwater, Babcock, Hilgard, Caldwell, Armsby, Jordan, Jenkins, Voorhees, Kedzie, Woods, Scovell, and Stubbs.

The study of the applications of chemistry to every kind of agricultural problems, which we group under the head of agricultural chemistry, has grown with ever-increasing momentum during these fifty years. I do not need to go into details before such a group as this.

The most accurate measure of the activity of chemical research in America is the published literature. The first chemical journal in the United States was *The American Chemical Journal,* founded by Ira Remsen just fifty years ago. We

now have not less than ten journals devoted exclusively to chemistry and six or more, containing matter devoted, in part, to chemistry. A single one of these journals, the *Journal of Biological Chemistry,* published last year 4272 pages, which, of course, refers to a single annual copy. I presume that a conservative estimate of all the American journals would furnish an aggregate of more than 20,000 pages.

It would be interesting to know how many chemists there are today in America. Fifty years ago very few commercial chemists were employed, and these mostly in steel-making plants, a few of the largest drug and chemical supply houses and, perhaps, an occasional one in some other line. To attempt to recapitulate the variety and number of different kinds of chemists in America is a task I will leave to some one who has more years ahead of him than has the speaker.

Finally, imagine, if you can, the state of mind in which any leading chemist of fifty years ago, who had passed away then, would be, if he were able to come to life now. Let him try to read an up-to-date elementary text-book of chemistry. He would find names of elements that did not belong there. He would be able to recognize scarcely any of the chemical formulas of compounds, organic or inorganic, and certainly not a single one of the structural formulas. He might wonder if s-u-l-f-u-r is one of the new elements. The atom, which in his day was a simple, indivisible particle, he would utterly fail to recognize in the one-to-several ringed circus of the present. Such words as ions, electrons, colloids, gels, adsorption, electrolytic dissociation, hydrogen ion concentration, radio activity and thousands of others would be absolutely meaningless to him. The symbol pH and many others which sprinkle the pages of chemical literature so generously today would have as much meaning to him as to an infant. Practically all of the terms used in biochemistry would signify nothing. All of the chemistry of the proteins would be wholly unintelligible. And so we might go on *ad infinitum, ad nauseam.* After hours or days of increasing, mystifying bewilderment, we can imagine him shaking his dizzy head, throwing up his hands in utter despair and vaporizing.

Sugar Prices

96° Centrifugals for the Period March 19, 1929, to June 15, 1929.

Date		Per Pound	Per Ton	Remarks
March	19, 1929	3.71¢	$74.20	Cubas.
"	22	3.695	73.90	Cubas, 3.71; Philippines, 3.68.
"	25	3.67	73.40	Porto Ricos.
"	26	3.64	72.80	Philippines.
April	3	3.595	71.90	Cubas, 3.61; Porto Ricos, 3.58.
"	5	3.55	71.00	Porto Ricos.
"	8	3.565	71.30	Porto Ricos, 3.55, 3.58.
"	9	3.625	72.50	Porto Ricos, 3.61, 3.64.
"	10	3.64	72.80	Porto Ricos.
"	11	3.69	73.80	Philippines, 3.67; Cubas, 3.71.
"	12	3.71	74.20	Cubas.
"	15	3.74	74.80	Porto Ricos.
"	16	3.69	73.80	Cubas, 3.71; Philippines, 3.67.
"	18	3.625	72.50	Philippines, 3.61; Cubas, 3.64.
"	19	3.61	72.20	Philippines.
"	25	3.71	74.20	Cubas.
"	26	3.68	73.60	Cubas.
"	30	3.58	71.60	Porto Ricos.
May	3	3.64	72.80	Porto Ricos.
"	6	3.595	71.90	Porto Ricos, 3.61; Cubas, 3.58.
"	8	3.58	71.60	Philippines.
"	9	3.565	71.30	Porto Ricos, 3.58, 3.55.
"	10	3.565	71.30	Porto Ricos, 3.58; Cubas, 3.55.
"	11	3.58	71.60	Cubas.
"	14	3.595	71.90	Philippines, 3.58; Cubas, 3.61.
"	15	3.595	71.90	Cubas, 3.61; Porto Ricos, 3.58.
"	16	3.58	71.60	Cubas.
"	17	3.595	71.90	Porto Ricos, 3.58; Cubas, 3.61.
"	18	3.61	72.20	Cubas.
"	20	3.596	71.93	Porto Ricos, 3.58; Cubas, 3.61, 3.60.
"	21	3.58	71.60	Porto Ricos.
"	22	3.55	71.00	Philippines.
"	24	3.58	71.60	Cubas.
"	28	3.565	71.30	Cubas, 3.55, 3.58.
"	29	3.535	70.70	Cubas, 3.55; Porto Ricos, 3.52.
June	3	3.49	69.80	Porto Ricos.
"	5	3.46	69.20	Philippines.
"	11	3.465	69.30	Cubas, 3.47, 3.46.
"	12	3.46	69.20	Cubas.
"	13	3.49	69.80	Philippines.

Sugar Prices

96° Centrifugals for the Period December 17, 1928, to March 15, 1929.

Date		Per Pound	Per Ton	Remarks
Dec.	17, 1928.....	3.93¢	$78.60	Cubas.
"	20..........	3.945	78.90	Cubas, 3.93, 3.96.
"	22..........	3.94	78.80	Cubas, 3.92, 3.96.
"	24..........	3.94	78.80	Cubas.
"	27..........	3.89	77.80	Cubas.
"	28..........	3.83	76.60	Cubas.
Jan.	3, 1929.....	3.77	75.40	Cubas.
"	5..........	3.80	76.00	Cubas.
"	7..........	3.83	76.60	Cubas.
"	9..........	3.815	76.30	Cubas, 3.83, 3.80.
"	12..........	3.83	76.60	Cubas.
"	14..........	3.80	76.00	Cubas.
"	15..........	3.785	75.70	Cubas, 3.80, 3.77.
"	16..........	3.80	76.00	Cubas, 3.77, 3.80, 3.83.
"	17..........	3.815	76.30	Cubas, 3.80, 3.83.
"	18..........	3.80	76.00	Porto Ricos.
"	29..........	3.81	76.20	Porto Ricos, 3.77; Cubas, 3.80, 3.86.
"	30..........	3.80	76.00	Cubas.
Feb.	1..........	3.77	75.40	Cubas.
"	5..........	3.74	74.80	Cubas.
"	8..........	3.77	75.40	Cubas.
"	11..........	3.74	74.80	Cubas.
"	13..........	3.725	74.50	Cubas, 3.74; Porto Ricos, 3.71.
"	14..........	3.72	74.40	Cubas.
"	15..........	3.74	74.80	Cubas.
"	18..........	3.71	74.20	Philippines.
"	25..........	3.715	74.30	Porto Ricos, 3.71; Cubas, 3.72.
"	26..........	3.725	74.50	Philippines, 3.71; Cubas, 3.74.
"	27..........	3.71	74.20	Cubas.
"	28..........	3.68	73.60	Philippines.
Mar.	2..........	3.71	74.20	Cubas.
"	4..........	3.725	74.50	Philippines, 3.71; Cubas, 3.74.
"	5..........	3.74	74.80	Cubas.
"	11..........	3.725	74.50	Cubas, 3.71, 3.74.
"	12..........	3.71	74.20	Cubas.
"	15..........	3.74	74.80	Porto Ricos.

// THE HAWAIIAN
PLANTERS' RECORD

Volume XXXIII. OCTOBER, 1929 Number 4

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In the death of Walter M. Giffard, at the age of 73, there disappeared from our midst a pioneer and a man prominent in the early organization of the Experiment Station. Long associated with the firm of W. G. Irwin & Company, Ltd., he thus became identified with the sugar industry in Hawaii.

As chairman of an organizing committee in 1903, he took a leading part in reorganizing the Hawaiian Sugar Planters' Association Experiment Station and thus took a major part in planning and directing the work of biological control of pests of the sugar cane, and subsequently, as a commissioner on the Board of Agriculture and Forestry of Hawaii, he planned the campaign for the search of parasites of the Mediterranean fruitfly and its introduction into the Territory.

It was while Mr. Giffard was chairman of the Experiment Station Committee that the department of pathology was originated. He also became interested in the production of cane seedlings and urged their propagation. H 109 and some others were derived from these early propagations.

Mr. Giffard showed a deep interest in entomology, and himself was an accurate and painstaking entomologist. He was one of the original members of the Hawaiian Entomological Society founded in 1905. His entomological papers deal chiefly with the native wasps and leafhoppers. His entomological collections, which were very complete, were willed to the Bishop Museum.

Mr. Giffard was a thirty-second degree Mason, and a member of many other organizations.

In This Issue:

Kohala 107 vs. D 1135:

In a test at Hawi, Kohala 107 was compared with D 1135 in a test of over ten repetitions of each variety. The cane was first ratoons, nineteen months old when harvested in July. The field was at an elevation of 325 feet and irrigated.

Kohala 107 proved itself to be consistently better than D 1135, averaging one ton of sugar more per acre, a gain of 21 per cent.

Also, as plant cane in this area, Kohala 107 was superior to D 1135, but not so much. This would indicate Kohala 107 to be a good ratooner.

Overhead Irrigation at Waipio:

A test harvested at Waipio recently showed no differences in yield of cane or sugar from overhead and contour irrigation.

The overhead system required about 25 per cent less water per unit of sugar produced.

The overhead system used 9.1 acre inches of water per ton of sugar, 245,600 gallons. (This is net water, measured at the pump.) The contour system used 11.4 acre inches of water per ton of sugar, 309,000 gallons.

In a later article, types of sprinklers will be discussed.

Cane Pulp as a Carbonaceous Food for Animals:

W. P. Naquin, manager of Honokaa Sugar Company, describes the feed now being used for the work animals of that plantation. This feed is composed of dry, screened bagasse, molasses and soya bean oil meal in the proportion 100-100-50. No other feed is used. It is used at the rate of three pounds for each hundredweight of live weight of animal per day.

The results are reported to be entirely satisfactory, the animals showing a slight gain in weight since this mixture has been put into use.

The cost of this new feed amounts to about 25 cents per animal per day, the average saving being close to $50 per animal per year.

Can We Select Potted Seedlings at Planting Time:

The above question is still unsettled. Answers have been both for and against it by different workers.

The behavior of 5,000 pot seedlings was studied at the Makiki plots. They

were graded as to vigor within one month after planting in the field and again when twelve months old.

The general average grade of the seedlings graded most vigorously as young plants was higher in the final selection than in the other two classes.

The results tend to show that an elimination of 10 to 20 per cent of the very uniform young plants is safe. A higher elimination involves more danger of discarding vigorous plants, but the average vigor of the plants will increase as the standard of selection is raised.

Notes on Javan Termites:

The termite species of the Netherlands East Indies appear to be primarily pests of certain agricultural crops, notably of teak and of *Hevea* rubber, rather than of buildings and wooden structures. Several natural enemies of termites, most of them predators, and only three true parasites, occur in the Malay Archipelago, but none of them is sufficiently effective to warrant introduction into Hawaii. The termite problem here is primarily an urban one, while such termite enemies as are present in Java are adapted to forest conditions.

Suggestions on Experimental Technique:

E. E. Naquin presents an interesting article on the above subject in this issue.

In testing cane varieties he stresses the importance of having the plot extend entirely across the field in order that all soil types may be included. In harvesting, areas in the various soil types should be handled separately, such as the good soils in the bottoms, medium soils on the slopes, and generally poorer ones on the hilltops. He shows that varieties respond very differently as conditions change.

In comparing D 1135 and Uba, for instance, he found D 1135 to be superior on the better soils, but on the thin, poorer types of soil Uba was distinctly better. Had the entire area been harvested as a unit these differences would not have been noted.

In planning the experiment care should be taken to have canes of more or less similar type adjoin each other. It will not do to have Badila next to U. D. 110 because the fast-growing U. D. 110 will soon shade out the Badila.

The same care in covering the various soil types is stressed for fertilizer experiments also. In fertilizer experiments provision must be made for guard rows as the border effect is very marked for at least 10 or 12 feet.

All of these points are well illustrated by a series of five photographs.

Bud Selection:

In this issue we give the results of a bud selection test harvested at Waipio.

A number of what were considered good and poor H 109 progenies were planted with adjacent unselected H 109.

The results show, in this crop, with ten replications of each, that progeny 172 and progeny 68 were consistently better than adjoining unselected H 109.

The test is being continued on the ratoon crop to be harvested next year.

The Mitscherlich Method of Soil Testing and Interpretation of Results:

W. J. Hartung describes the Mitscherlich method of conducting pot experiments for determining soil fertility and gives the methods used for calculating and interpreting the results.

The article does not very well lend itself to abstracting because, although somewhat long, it is in the nature of an abstract itself.

We therefore suggest that the article be read by all those interested.

Chemical Control in Construction of Hydraulic Earth-Fill Dams:

A report on an investigation of hydraulic dam construction appears in this issue. Mainland practices in building technic and control operations are described.

A discussion is included which covers the development of the engineering and chemical "control" which is now in operation at the construction of the Alexander Dam of the McBryde Sugar Company, Ltd., at Eleele, Kauai.

Fourth Pacific Science Congress:

In a report on the Fourth Pacific Science Congress, which convened at Batavia and at Bandeong, Java, May 16 to 29, 1929, is given a general account of the sessions and scientific excursions held there, and attention is called to some of the prominent features of the Congress and of the important papers presented.

Third Congress of International Society of Sugar Cane Technologists:

An article is presented listing the names of the delegates who attended the Third Congress of the International Society of Sugar Cane Technologists which was held in Java, June 7 to 19, 1929. The delegates are listed with their titles and addresses under the name of the country they represented. A photograph of each delegate with the exception of three is also shown. The names of many Java members of the Society who took an active part in making the Conference a success are also listed as published in the official program of the Congress.

Walter M. Giffard

By O. H. Swezey

In the death of Walter M. Giffard, June 30, 1929, a man prominent in the early organization of the Experiment Station, H. S. P. A., and who has always had its interests at heart, passed to his reward.

Mr. Giffard came to the Hawaiian Islands in 1875 at the age of 19. He soon (1877) joined the firm of W. G. Irwin and Company, Ltd., and thus became connected with the sugar industry at an early date, and soon rose to prominence during the time that rapid development of this industry was taking place in Hawaii. From bookkeeper he was promoted, in turn, to treasurer, secretary, and finally vice-president, which office he held at the time when W. G. Irwin and Company, Ltd., dissolved, in 1909, and its interests were consolidated with C. Brewer & Company, Ltd. At that time Mr. Giffard retired from official business life, although he was still a director in several of the sugar plantation companies for whom the W. G. Irwin Company had been agents.

Mr. Giffard's special interest in the Experiment Station began in 1903, when, as chairman of an organizing committee, he took the leading part in a reorganization of the Experiment Station during the course of which a department of entomology was created. This new department had become necessary on account of the devastation caused by the sugar cane leafhopper pest (*Perkinsiella saccharicida*), whose introduction from Australia had occurred a few years previously, and which had now become spread throughout the sugar plantations of the islands and was threatening to ruin the industry. Dr. R. C. L. Perkins was chosen to head this new department of entomology, with Messrs. G. W. Kirkaldy and F. W. Terry, who had been connected with the Territorial plant quarantine inspection work, to assist him. In 1904, this entomological staff was increased by the addition of O. H. Swezey, and in 1905 F. Muir was added to the staff. The early work of the department of entomology involved the study of the leafhopper in Hawaiian cane fields, and the introduction of natural enemies of the leafhopper from other lands. Thus was Mr. Giffard instrumental in the application of this line of entomology to the sugar industry, following the valuable work of Albert Koebele, who had for about ten years been engaged in introducing ladybeetles and other natural enemies for the control of horticultural pests—a method of insect pest control that has continued in practice and has been eminently successful in Hawaii.

It was while Mr. Giffard was the chairman of the Experiment Station Committee that the department of pathology was originated in 1904 and Dr. N. A. Cobb obtained as its head.

Mr. Giffard also became interested in the attempt to produce cane seedlings, and it was due to his urgent appeal that the propagation of seedlings was finally inaugurated in the season of 1904-5. The celebrated H 109 and several other varieties of notable value were derived from these early propagations.

For a long period of years (1903-1923) Mr. Giffard was a commissioner on

the Board of Agriculture and Forestry of Hawaii, of which he was president for three terms. In connection with this he was much concerned with the horticultural interests of the Territory, and was largely responsible for the promulgation of plant quarantine regulations for the purpose of preventing the entry of additional insect pests to these islands. When the Mediterranean fruitfly made its appearance in 1910, it was Mr. Giffard who headed a clean-up campaign in an endeavor to control the pest and lessen the injury to fruit by its maggots. On the failure of this endeavor, Mr. Giffard planned the campaign for the search of parasites and their introduction, which resulted in the introduction of five species of parasites from Africa and Australia, and a subsequent reduction of fruitfly damage.

From Mr. Giffard's interest in the department of entomology during the time he was involved in its organization, and while chairman of the Experiment Station Committee (1903-1907), and his association with the entomologists, he became keenly interested in entomology and took up insect collecting as a recreation. After his retirement from active business he had much time for this, and built up large collections of the native Hawaiian insects, which, in several groups, or important families, were more complete than any other collections in Honolulu. On his death, these were willed to the Bishop Museum.

When the Hawaiian Entomological Society was founded in 1905, Mr. Giffard was one of the original members, and was always a staunch supporter of the society. He was twice president, and contributed numerous papers resulting from his studies of the insects he had collected. Those of notable importance dealt with Hawaiian wasps and leafhoppers, his interest in the latter group having been aroused by reason of the fact that it was a leafhopper pest that had made the occasion for a department of entomology to be organized at the Experiment Station and the part that he had had in this. A closely related group, the Hawaiian Cixiidae, was carefully studied, and a monographic revision of this family by him was published in the Proceedings of the Hawaiian Entomological Society and constituted his most important entomological paper. Many new species of insects were named for Mr. Giffard, a good proportion of them being species discovered by him. Further plans for continuing his studies with Hawaiian insects were cut short by the prolonged illness from which he finally succumbed on June 30, at the age of 73 years.

Mr. Giffard was a 32nd Degree Mason, Knight Templar and Shriner, honorary member of the Honolulu Chamber of Commerce and of the Hawaiian Sugar Planters' Association, fellow of the Entomological Society of London and of the American Association for the Advancement of Science, member of American Association of Economic Entomologists, Biological Society of Washington and Pacific Coast Entomological Society; charter- and life-member of the Entomological Society of America.

Kohala 107 Surpasses D 1135 in Test at Hawi

HAWI MILL AND PLANTATION COMPANY EXPERIMENT 12-V

By J. A. Verret

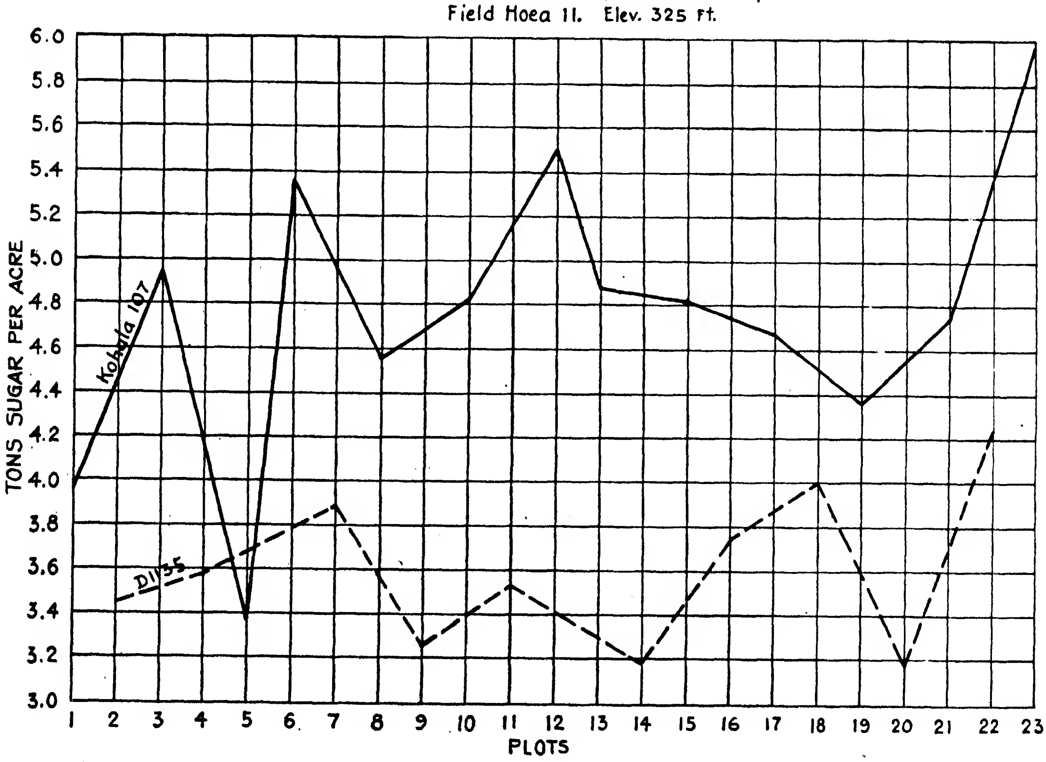
The cane in this test was first ratoons, nineteen months old when harvested in July, 1929. The field was an irrigated one at an elevation of 325 feet. The layout comprised twenty-three plots, thirteen of which were K 107 and ten D 1135. Each plot was two watercourses in size. All plots received uniform fertilization.

K 107 was consistently better than the adjoining D 1135 and averaged over one ton of sugar more per acre than the D 1135. The odds according to Student's Method, that this gain of one ton of sugar is not due to chance, were 9999 to 1. The yields by plots are shown graphically in the accompanying illustration.

The average yields for the plant and first ratoon crops are given below:

Variety	No. of Plots	T.C.P.A. Plant	T.C.P.A. Ratoon	Q.R. Plant	Q.R. Ratoon	T.S.P.A. Plant	T.S.P.A. Ratoon
K 107	13	47.6	35.25	9.50	7.46	5.02	4.73
D 1135........	10	45.0	27.47	9.80	7.60	4.60	3.61

KOHALA 107 VS. D-1135
1 st. Ratoons 19 Months Old At Harvest
Hawi Mill & Pl. Co. Expt. 12V, 1929 Crop
Field Hoea 11. Elev. 325 Ft.



In both of these harvests we note the juice of K 107 to be somewhat better than that of D 1135. K 107 gives indications of being a good ratooner.

The behavior of K 107 in rather extensive plantings shows it to be resistant to eye spot, mosaic and red stripe. It closes in somewhat faster than D 1135, and as a rule is not a free tasseler.

The summary of this year's harvest and the detailed yield by plots are given as follows:

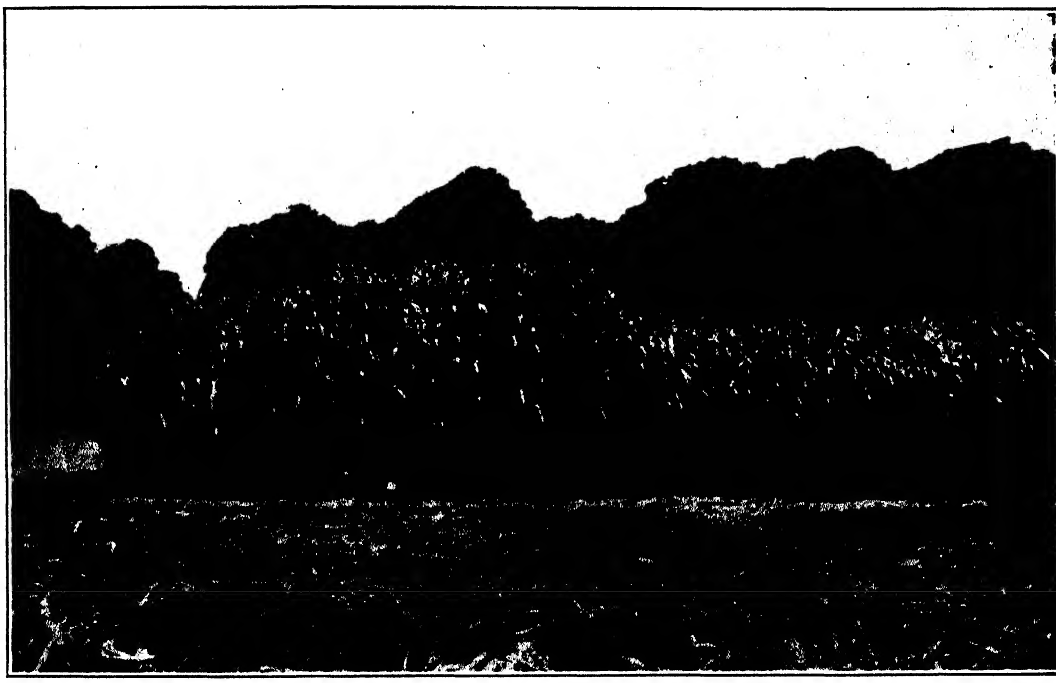
Summary of Results

Variety	Area	T.C.P.A.	Per Cent Gain	Q.R.	T.S.P.A.	Per Cent Gain	T.S.P.M.
K 107.........	1.8290	35.248	22.07	7.46	4.73	20.86	.28
D 1135.........	1.3914	27.468		7.60	3.61		.22

PLOT YIELDS

Plot	Tons Cane	Area	T.C.P.A.	Brix	Poln.	Purity	Q.R.	T.S.P.A.
6 K	4.43	.1148	38.6	21.41	18.67	87.2	7.22	5.35
13	3.41	.0926	36.8	20.71	17.92	86.5	7.56	4.87
1	6.33	.2259	28.0	21.19	18.57	87.6	7.24	3.87
15	3.90	.1048	37.2	21.51	17.99	83.6	7.74	4.81
8	4.60	.1462	31.5	22.20	19.44	87.6	6.91	4.56
3	6.54	.1874	34.9	21.59	18.83	87.2	7.16	4.87
17	5.41	.1571	34.4	21.26	18.42	86.6	7.36	4.67
10	3.94	.1146	34.4	21.66	18.88	87.1	7.15	4.81
5	2.84	.1167	24.3	21.36	18.71	87.5	7.19	3.38
19	4.92	.1353	36.4	20.69	16.96	81.9	8.34	4.36
21	4.75	.1250	38.0	21.26	17.57	82.3	8.02	4.74
12	5.28	.1276	41.4	21.46	18.25	85.0	7.53	5.50
23	8.12	.1810	44.9	21.23	18.20	85.6	7.51	5.98
Total....	64.17	1.8290						
True Ave...			35.248				7.46	4.73
7 D..........	3.79	.1384	27.4	22.01	19.15	87.0	7.05	3.89
14	2.25	.0939	24.0	20.78	17.99	86.6	7.53	3.19
2	5.03	.2007	25.1	21.72	18.73	86.1	7.27	3.45
16	3.30	.1186	27.8	21.21	18.33	86.4	7.41	3.75
9	3.76	.1541	24.4	21.50	18.25	84.8	7.54	3.24
4	3.96	.1508	26.2	21.94	18.77	85.5	7.29	3.59
18	5.01	.1584	31.6	21.29	17.70	83.1	7.90	4.00
11	2.55	.0971	26.3	21.75	18.45	84.8	7.46	3.53
20	3.63	.1313	27.6	20.56	16.56	80.5	8.67	3.18
22	4.94	.1481	33.4	21.19	17.68	83.4	7.89	4.23
Total....	38.22	1.3914						3.61
True Ave...			27.468				7.60	

P. O. J. 2878



P.O.J. 2878 on left, standard canes on right. Seven months old plant cane when photographed on August 14, 1929.

Notes on Overhead Irrigation at Waipio Substation

By F. C. Denison

This year we harvested our first crop grown under overhead irrigation. The overhead system was installed in the first ratoon crop, the plant crop having been raised with the contour system. In Fig. 1 a plan of the layout is shown giving the various sizes of pipe and the spacing of laterals and sprinklers. The spacing which we used was based on results of work done by us at the Oahu Sugar Company's baseball park where we determined the distribution and the discharge of water for varying pressures. Fig. 2 shows the distribution that we obtained in our field when the sprinklers were operated at a nozzle pressure of 30 pounds for a period of 12 hours. At the end of the time the depth of water was measured in each tin and recorded as shown in the illustration.

At this point it would be well to bring up the effect of wind on tests and distribution. We have found that much better distribution is obtained if the irrigation is done at night when there is generally less wind than in the daytime. In any layouts for overhead irrigation one must be very careful to take the wind into consideration, especially along the edges of the field. This was clearly brought out in our layout. We should, from our distribution figures, get enough water along the roadside of our layout to give a thorough irrigation, but we did not. In the laterals where the sprinklers are 36 feet from the edge of the field the distribution against the wind was poor and we had spots with insufficient irrigation. This is now being corrected by installing a sprinkler with greater coverage, or it could be corrected by the addition of two small sprinklers on these laterals. We also found that distribution tests should be repeated several times in order to get reliable data, and where wind is a big factor the tests should be repeated even more than usual.

In order to substantiate our distribution results an attempt was made to check it with soil moisture. This proved to be very discouraging as the effect of various factors over which we had no control caused such varying results that no definite conclusions could be obtained. We were, however, able to get results on some of our moisture work in comparison with the adjoining field, which was irrigated by the contour method. The soil moisture samples were taken to a depth of 4 feet two days before and two days after each irrigation. In the sprinkler field seven borings were taken spaced 10 feet apart between two sprinklers in adjoining laterals while in the contour field borings were taken in various watercourses, being careful to keep 30 feet from the level ditches and at least 10 feet from the watercourses. In both fields the borings before and after irrigation were taken within a foot of each other. A 3-acre-inch irrigation applied to the overhead field would increase the soil moisture from 26 per cent to 30 per cent. We were able to account for about 55 per cent of the water in the first 4 feet. In the contour field a 3-acre-inch irrigation would increase the soil moisture from 26 per cent to 29 per cent in the first 4 feet. In other words, we were able to account for

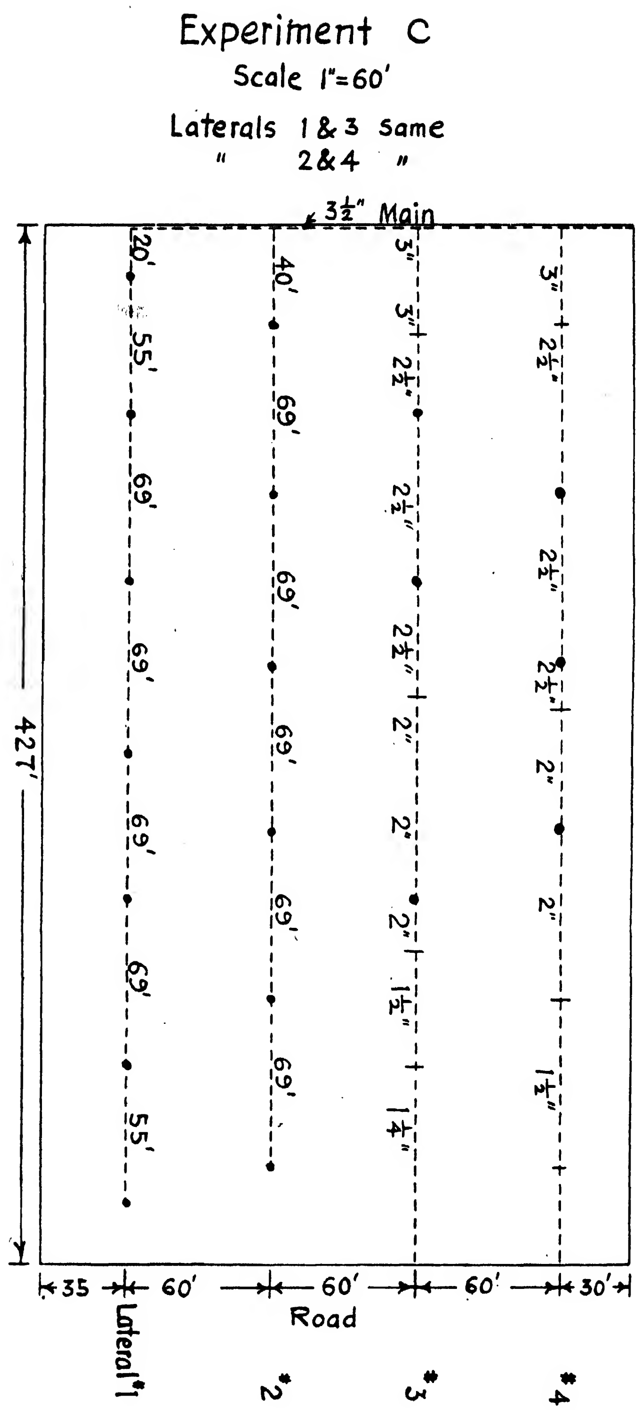

Experiment C
Scale 1"=60'
Laterals 1 & 3 same
" 2&4 "
3½" Main
427'
35
60'
60'
60'
30'
Road
Lateral #1
#2
#3
#4

Fig. 1

about 30 per cent of the 3-acre-inch irrigation. The loss of water by deep percolation in the level ditch and watercourses probably accounts for the difference between the two fields.

The results in yields of the two adjoining fields are tabulated below. In the previous crop, when both fields were under contour irrigation, there was no essential difference between the yields of the two. The water for the overhead field is measured by a Great Western meter as the water enters the sump, while the water for the contour field was measured by a Great Western meter installed at the head of the level ditch.

Field	T.C.P.A.	Q.R.	T.S.P.A.	No. of Irrigations	Ac. In. Rain	Ac. In. Irrigation	Total	Ac. In. T.T.C.	Ac. In. T.T.S.
C overhead	101.82	6.82	14.93	32	29.13	105.94	135.07	1.04	9.1
D contour	103.95	6.92	15.02	32	30.99	140.81	171.80	1.35	11.4

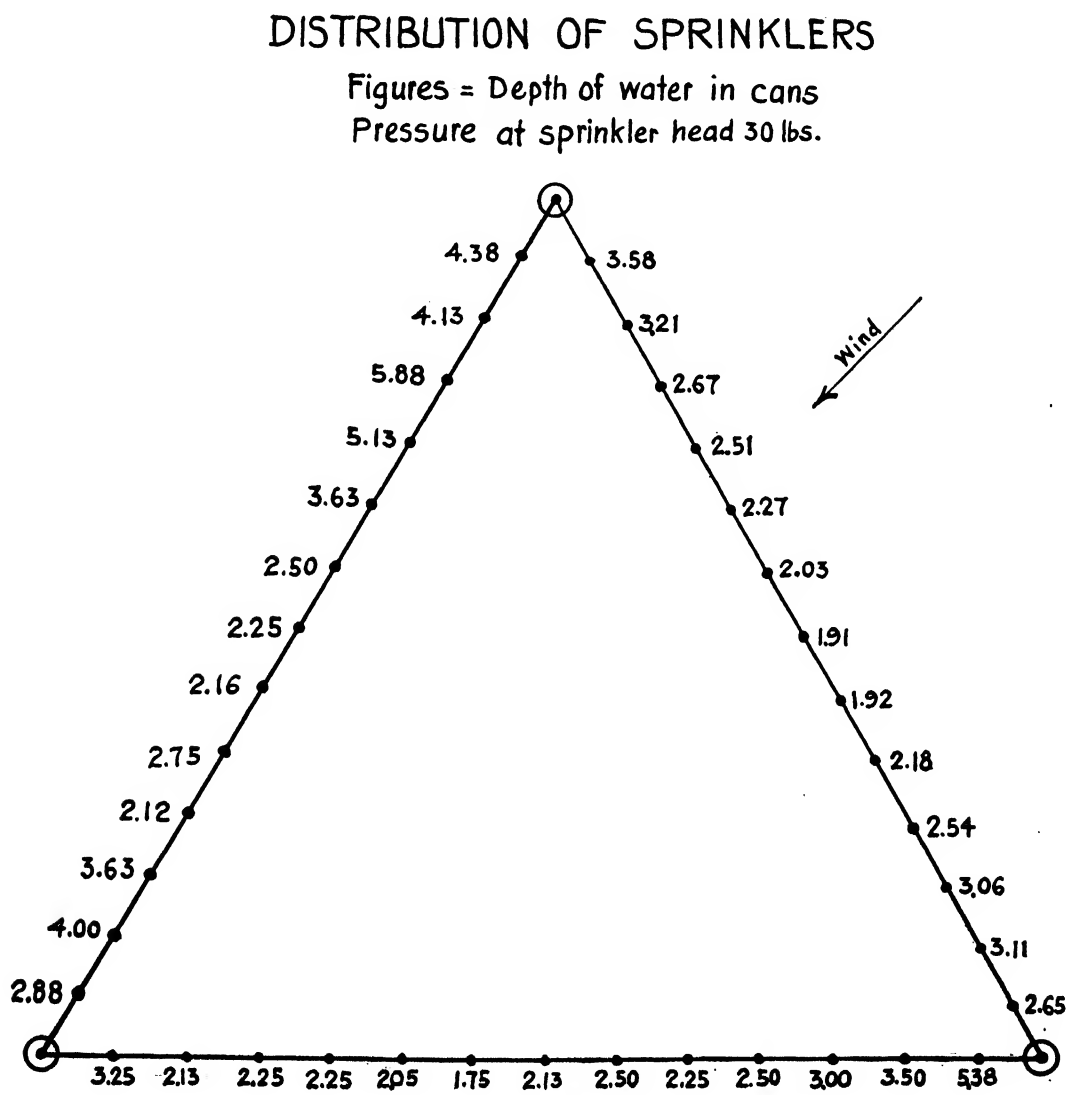


Fig. 2

The results show no significant difference in yields. The sprinkler field used less water and produced more sugar per unit of water used.

In order to compare costs and state whether or not overhead irrigation pays is rather hard with our present outlay. Our pump has a capacity of 200 g. p. m., which with our layout means we are able to irrigate about 1.5 acres as a unit. This means that the labor is higher than for the standard method. If it were possible for us to irrigate from 10 to 20 acres as a unit it would be possible for the same men to handle it equally as efficiently as they do the smaller units. This, however, is only a part of the subject as it is necessary to consider the saving or additional expense for all the operations. The changes in costs which have been noted in our layout are submitted for the reader's consideration.

Plowing: Increased cost for overhead removing lateral pipes and relaying some.

Preparing: Less cost for overhead—deep lines not necessary and lines can be straight as there is no need to follow the contour of the land.

Planting: About the same cost.

First irrigation: Less for overhead as there is no work to be done in building up watercourses.

Irrigation: Less cost for labor in overhead, no level ditch losses.

Weeding: Overhead system requires more weedings, but this can be done by animal or power cultivation.

Stripping: About same as it is necessary to strip along the laterals to facilitate care of sprinklers.

Fertilizing: Fertilizer can be applied by sprinklers very cheaply. We applied 488 pounds A. S. per acre without any serious or noticeable burning effect to the cane.

Ratooning: Advantage for overhead as it is not necessary to repair watercourses and lines.

Harvesting: About the same.

Capital invested: Depreciation on pipe and sprinklers plus initial cost are very large. Additional cost if it is necessary to develop pressure by installation of a pump.

Cane Pulp as a Carbonaceous Food for Animals

By W. P. Naquin

The principal part of feed for animals consists of proteid, carbohydrate, fat, fibre and certain mineral salts and vitamins. For the best results these bodies must be combined in certain proportions, one to the other, and, above all, this combination must be palatable.

On a sugar plantation we have an overabundance of carbohydrate and fibre; in fact sugar cane comes very close to being a pure carbohydrate plant, since all of the sugar, pulp and molasses come under this heading. The sugar, as well as the molasses, is extensively used as a carbonaceous food, both for humans and animals. So far, cane pulp, although it contains 47 per cent digestible carbohydrate, has received but scant attention from farmers and feeders.

A few plantations in the Islands have used the cane pulp as a vehicle for molasses, with indifferent results, the bulk of the carbohydrate and fibre being supplied by cane tops, barley, hay, etc. On account of the distance from the mainland, such materials as barley, hay, etc., are very expensive feed; even the cane tops must be gathered, transported and prepared for feeding, and become a costly ingredient, especially when one considers that their counterparts can be had with the already available cane pulp and molasses.

The composition of cane pulp and molasses, as given by Henry & Morrison in *Feeds and Feeding*, as compared with the expensive imports commonly used in feeding work animals in the Territory, is as follows:

		Digestible Nutrient Per 100 Lbs.				
	Total Dry Matter Per Cwt.	Crude Proteid	Carbo-hydrate	Fat	Total	Nutritive Ratio
Cane pulp	89.9	.5	47.6	3.3	55.5	1 : 110
Molasses	74.3	1.0	58.5	.0	59.5	1 : 58.5
Barley	90.9	9.0	66.8	1.6	79.4	1 : 7.8
Oats	90.9	9.7	52.1	3.8	70.4	1 : 6.3
Barley hay	92.9	4.6	48.2	.9	54.8	1 : 10.9
Beet pulp	90.8	4.6	65.2	.8	71.6	1 : 14.6

Both cane pulp and molasses compare favorably as to the amount of total digestible carbohydrate in most feeds. This carbohydrate in barley and oats is of a starchy nature. The carbohydrate in cane pulp consists mostly of pentosan, sugar and digestible cellulose, integration product of starch, while the carbohydrate of molasses is mostly sucrose and reducing sugars.

In the animal bodies such bodies as starch and cellulose must be disintegrated or broken down to the lower sugars before they can be absorbed by the animal. To what extent these cellulose compounds and the sugars in molasses can be substituted for the starch in a feed is of great economic importance.

In 1927, Honokaa Sugar Company undertook some experiments to learn the

feasibility of utilizing cane pulp, mixed with molasses, solely as the carbonaceous portion of a ration for work animals. To properly balance a ration it was necessary to have a feed high in protein; such a feed we have in soya bean meal.

A balanced ration for hard working animals, using the Wolff & Lehmann standard, was made up as follows:

		Pounds Digestible Matter		
	Dry Matter	Protein	Carbohydrate	Fat
Cane Pulp, 100 lbs.......	89.8	.5	47.6	3.3
Molasses, 100 lbs.........	74.3	1.0	58.5	.0
Soya Bean Oil Meal, 50 lbs.	44.4	19.85	17.3	2.2
Average Composition	83.5	8.54	49.3	2.2

Nutritive Ratio—1 : 6.4

As the cane pulp coming from the mill is too coarse and too moist to use as such, it was necessary to put up a screening and drying plant so as to take the least fibrous portion of the pulp and bring it down to a moisture content that would prevent fermentation. This was easily managed by placing a steel plate 2½ x 5 feet, containing four thousand ⅜-inch holes at the bottom of the main bagasse carrier. The pulp, so screened, is carried to an enclosed cross-carrier through the main flue leading to the smokestack, where the moisture content is reduced to 11 per cent. This is then carried and blown with a suitable blower to a storage room where it is kept until used.

The pulp is mixed with soya bean meal and molasses, in the correct proportions, in an ordinary feed mixer, as feed is required.

Since September, 1927, all of the working animals of the Honokaa Sugar Company, some 400 in number, were placed on the above ration—this being the only feed. Previous to this we had fed a balanced ration consisting of barley, alfalfa meal, cane tops and molasses, with a small portion of cane pulp as a carrier for the molasses.

Although we realized that a gradual change from such a ration to the new one would be desirable, yet in our case we did not feel that the change, from any standpoint, would be sufficiently great to justify prolonging the change; consequently it was made overnight, without any unfavorable reaction.

From then on we have been feeding the ration consisting of 3 pounds of this mixture for each hundredweight of live weight of animal per day, and the results have been entirely satisfactory; not only have we had less sickness in our stables, but there has been a decided improvement in the condition and appearance of our stock.

The cost of this new feed amounts to around 25 cents per animal per day, and the average saving we have made is close to $50.00 per head per year.

At the time of the change we selected twenty animals, which were weighed then and several times thereafter, to see what changes would take place in their physical condition; a list of these weights is given hereunder:

WEIGHT OF TWENTY MULES OF HONOKAA SUGAR COMPANY

	Sept. 18, 1927	Oct. 30, 1927	Dec. 3, 1927	Feb. 5, 1928	Since Sept. 18, 1927 Gain	Loss
1	1,480	1,560	1,560	1,480	...	...
2	1,480	1,520	1,560	1,620	140	...
3	1,420	1,440	1,420	1,420	...	...
4	1,380	1,340	1,380	1,420	40	...
5	1,300	1,320	1,300	1,320	20	...
6	1,260	1,260	1,240	1,280	20	...
7	1,180	1,140	1,200	1,160	...	20
8	1,140	1,200	1,200	1,260	120	...
9	1,100	1,080	1,120	1,040	...	60
10	1,080	1,100	1,040	1,020	...	60
11	960	960	960	980	20	...
12	920	960	940	980	60	...
13	920	1,000	960	940	20	...
14	800	840	820	800	...	...
15	840	840	880	840	...	...
16	800	800	820	840	40	...
17	840	860	860	900	60	...
18	740	780	780	860	120	...
19	720	760	760	800	80	...
20	580	620	600	640	60	...
	20,940	21,380	21,400	21,600	800	140

Twenty animals:	Gain...........	800 pounds
	Loss	140 pounds
	Net Gain ...	660 pounds

From the above table it will be seen that there was very little fluctuation in the weight of the animals from month to month, and as a whole, the twenty animals under observation gained in weight.

This fact, combined with the experience gained through two years feeding, has convinced us that the carbohydrate in cane pulp and molasses answers the bodily requirements of the working animals. When mixed with a suitable proteid body, the feed proves very palatable and the animals take to it readily.

It has also proven satisfactory as an exclusive feed for brood mares. We have several colts of around one year old, whose mothers were given this ration and the young animals appear normal in every way.

The by-products from the beet and pineapple industries have found their niche in the markets of the world, and the writer feels that in cane pulp we have a product similar to these and that eventually its worth will be recognized.

Can We Select Potted Seedlings at Planting Out Time?

By C. G. Lennox

Numerous attempts have been made to answer this question. Answers have been given both in the affirmative and the negative. Dr. O. Posthumus (1) cites experiments where ten very vigorous and ten weak seedlings were selected from a single lot. The results at maturity showed no correlation with the early selection. Y. Kutsunai (2) selected 138 large and 138 small seedlings from the same parentage lot. These were planted in four units, a large classification alternating with a small classification. At the end of twelve months the four units were harvested. A partial tabulation of the data follows:

	Large Seedlings	Small Seedlings
Total number of seedlings planted..........	138	138
Total number of sticks harvested............	1034	776
Average weight of cane per stool............	23.8 pounds	15 pounds
Number of seedlings selected as superior....	18	3

His conclusion is: "Selection of seedlings in pots as to size is effective."

In answer to the question: "What percentage of the seedlings, if any, is eliminated before setting out in the field?" San Manuel, Cuba, and Insular Experiment Station, Porto Rico (3), answer 90 and and 95 per cent are eliminated on the basis of vigor, etc. Mauritius, Virgin Islands, Soledad (Cuba), Florida and the U. S. Department of Agriculture Station at Porto Rico report an elimination of from 50 to 75 per cent before planting in the field.

The Problem

The question to be answered is: With what degree of sureness can we eliminate weak-appearing seedlings which are still in pots, and what is a safe percentage to discard? The study was planned to cover the relationship between very weak, medium, and very strong plants at the time of planting to the field and their distribution as inferior, doubtful, and very superior canes when judged by appearance at twelve months. This age is commonly recognized as the optimum time to make selections.

Will most of the seedlings which appear very strong as small plants of eight to ten inches in height still be the superior ones when they are twelve months old?

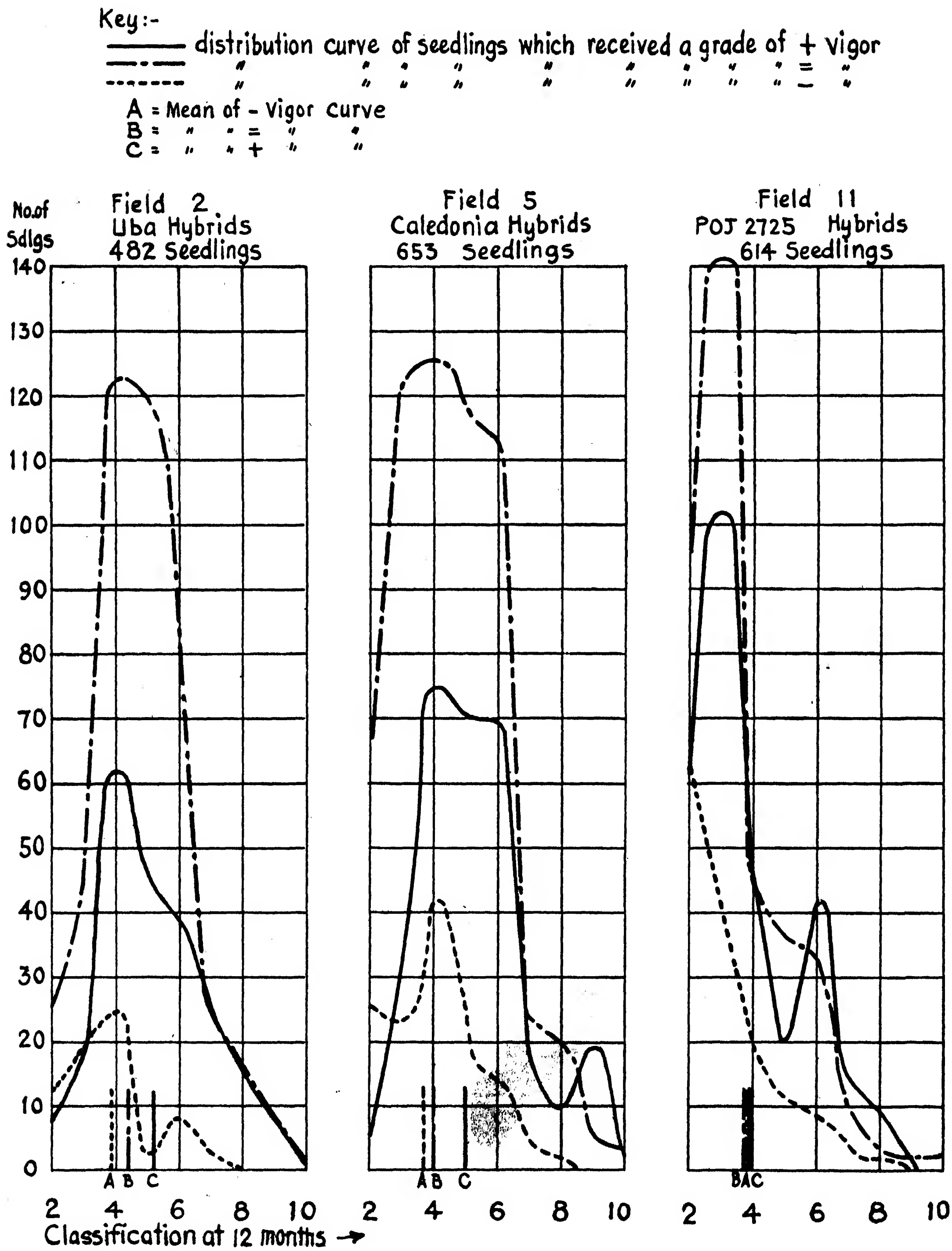
Terminology

A brief discussion of the terms used in this paper follows:

Vigor—a term used to denote the general growth characteristics of young seedlings. It includes tillering, greenness, speed of growth and general healthiness.

Minus (—)—denotes decided inferiority.

DISTRIBUTION CURVES OF FINAL GRADINGS CLASSIFIED ACCORDING TO GRADING AT PLANTING TIME



Equal (=)—is a classification which is neither decidedly inferior nor decidedly superior.

Plus (+)—denotes decided superiority.

Gradings—the classification of the seedling at the age of twelve months. The most inferior receive a — or 1 grade, while the superior receive + or 5. The other classes are = — 2, = 3, and = + 4. In all cases only the summation of the grades given by two men working separately and independently are given. Thus the lowest classification is 2 and the highest is 10.

Plan of Study

All the seedlings planted at the Makiki plots are given a permanent number on planting. Each seedling is then graded within one month after being transplanted from the pots, being classified as +, =, or — in vigor. Only the very weak ones were considered minus. No selection was made previous to transplanting and no efforts are made to segregate the weak from the strong at the time of planting into the field.

Between the ages of 12 and 14 months, two individuals, working entirely independently of one another, again grade each seedling on the basis of its agricultural qualities. Selection of the best canes is usually based on the grading at this age.

A quantitative study is made of the relationship between the rough classification at planting-out-time and the final selection-grading at 12 to 14 months.

An Interpretation and Analysis of the Results

A separate study was made of each field at Makiki because as a unit each field is more uniform, being generally of the same age when transplanted, the same general parentage, and often the same fuzz lot. A distribution curve of the final gradings was made for the +, = and — "planting-out-time" classification in each field to study the trend of these early gradings. Referring to the accompanying illustration, we find these curves plotted for three typical fields. A study of the distribution of the final gradings within the (+) plus vigor curve shows a tendency to have a general trend to the right. This is borne out when we find the mean (c) of the plus curves always to the right of the other means. In other words, the seedlings which were given a plus grade when planted out show a greater number of good seedlings at the final grading than either of the other groups. Likewise, those which were graded minus vigor at planting out time show a greater proportion of inferior seedlings at the final grading. But a study of the equal curve shows about an equal distribution on either side.

With these curves in mind we would never say that we are justified in selecting only the seedlings showing plus vigor for planting to the field, because there are actually more superior seedlings in the equal vigor group (refer to Table III). Possibly, though, we will be justified in the premise that the seedlings in the minus vigor group could be profitably eliminated as the potted seedlings are planted to the field. A more detailed study of these minus vigor curves therefore ensues.

Minus vigor distribution curves were constructed for all the fields at Makiki. The mean and standard deviation from the mean was calculated for each. These figures, along with the mean + twice the S. D., are tabulated in the following table:

TABLE I

A calculation of the mean and standard deviation of a number of "minus-vigor" curves. Twice the standard deviation includes 95 per cent of all possible observations.

Field No.	Parentage	No. of Seedlings	Mean of minus vigor curve	Standard deviation	Mean plus 2 standard deviation
(1)	(2)	(3)	(4)	(5)	(6)
2	Uba hybrids	29	3.86	±1.15	6.16
4	Caledonia hybrids	32	2.90	±1.38	5.66
5	Caledonia hybrids	47	3.85	±1.43	6.71
7	Caledonia hybrids	88	3.98	±1.75	7.48
12	P. O. J. 2364 hybrids	96	3.58	±1.23	6.04
13	Uba hybrids	55	3.25	±1.22	5.69
14	P. O. J. 2364 hybrids	61	3.24	±1.51	6.26
17	P. O. J. 2364 and Misc.	92	3.55	±1.52	6.59
18	P. O. J. 2364 and Misc.	86	3.04	±1.32	5.68
19	Miscellaneous	30	3.27	±1.26	5.79

Since twice the standard deviation of a mean in a normal curve includes approximately 95 per cent of all the observations composing the curve, we have recorded in column 6 the mean plus 2 S. D. An examination of these figures shows us very few which go above a grade of 6. A seedling with a grade of 6 or 7 would in all probability never be selected for spreading unless it showed a very high Brix. Therefore we might feel safe in assuming that of all the seedlings given a grade minus vigor at planting out time, approximately 95 per cent will never develop into superior seedlings.

Treating the same data as given by the minus-vigor curves on the basis of percentages occurring above or below assumed grades, we have Table II.

TABLE II

A summary of all the "minus-vigor" curves, showing the percentage of seedlings based on the total number in the field, which received the grade of 5 or poorer, 6 or better, and 7 or better.

Field No.	No. of Seedlings In field	Parentage	Percentage of 5 or below	Seedlings receiving a final grade of 6 or above	Seedlings receiving a final grade of 7 or above
(1)	(2)	(3)	(4)	(5)	(6)
2	482	Uba hybrids	5.0%	1.0%	.41%
4	398	Caledonia hybrids	6.8	1.3	..
5	653	Caledonia hybrids	6.0	1.2	.3
7	583	Caledonia hybrids	10.8	4.3	1.4
11	614	P. O. J. 2725 hybrids	22.4	2.6	1.3
12	339	P. O. J. 2364 hybrids	25.1	3.2	1.2
13	357	Uba hybrids	13.4	2.0	.28
14	294	P. O. J. 2364 hybrids	18.0	2.7	.7
17	666	Misc. P. O. J.'s	11.9	2.0	.45
18	460	Miscellaneous	17.4	1.3	.22
19	265	Miscellaneous	9.8	1.5	..
Total	5111		146.6	23.1	5.99
Weighted averages			13.0%	2.1%	.6%

We see from the averages in the above table that should we have eliminated approximately 15.1 per cent (13.0 per cent + 2.1 per cent) of the very poor seedlings at planting out time from the total of 5,111 planted, only about 2.1 per cent of this total would have a grade of 6 or better, and only .6 per cent would have a grade of 7 or better.

Assuming that a final grade of 8 or better is necessary to be assured that a seedling will be kept on agricultural appearance alone, we have tabulated in Table III the actual number of seedlings in each of the vigor groups which received such a grade.

TABLE III

A summary of the number of seedlings in each "planting-out-time" rating group having a final grade of 8 or better.

Field No.	No. of Seedling	No. of seedlings receiving a grade of 8 or better in: Minus-vigor group	Equal-vigor group	Plus-vigor group
2	482	1	29	10
4	398	0	18	12
5	653	1	29	13
7	583	2	23	16
11	614	5	6	5
12	339	3	6	0
13	357	1	20	13
14	294	2	14	4
17	666	3	25	11
18	460	0	5	9
19	265	0	14	9
Totals	5111	18	189	102
Percentage of total		.35%	3.7%	2.0%

From this table we readily see that to make a preliminary elimination greater than of those seedlings in the minus group would be wasteful, for about 94 per cent of all the selected canes fall in these two higher groups, and to retain only the most vigorous seedlings at planting out time would mean the loss of 60 per cent of the superior seedlings which are contained in the other two groups. On the other hand, if it is desired to eliminate the very poorest ones to an extent of 10-20 per cent of the total, then the loss would only be about one superior seedling in every 288.

Conclusions and Summary

A total of 5111 pot seedlings of many different parentages were planted in the plots at Makiki in 1928. No elimination or segregation was made previous to planting.

All seedlings were graded as to vigor within one month after planting. All seedlings were again graded at the age of twelve months by two individuals.

A study of the relationship between the early and final gradings was made. No attempt was made to determine the relationship between an early selection and the canes which show commercial value after years of testing.

The general average grade of the seedlings graded most vigorous as young plants was higher in the final selection than in the other two classes.

An elimination of 10-20 per cent of the very inferior young plants would seem to be a safe practice preceding planting into the field. Such would only occasion the loss of about one superior cane in 288.

Elimination of larger percentages will result in the loss of larger numbers of superior seedlings.

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(1) Posthumus, O. The Selection of Seedlings Before Transplanting Into the Fields. Archief 1929, Part I, No. 13, pp. 379-382.

(2) Kutsunai, Y. Seedling Selection—Report in Project File, H. S. P. A. Experiment Station Library.

(3) Association of Hawaiian Sugar Technologists, Report for 1927, pp. 80-100.

Notes on Javan Termites and Termite Enemies

By R. H. Van Zwaluwenburg

The visitor to Java is impressed by the relative unimportance of termites in that tropical island. It is, of course, true that these insects cause considerable destruction of wooden structures and of certain agricultural crops, but their damage is less conspicuous than the writer expected. Although termites are abundant in forested regions, houses in the towns and villages do not seem to suffer to any very great extent. The extent to which natural factors operate to hold white ants in check was the writer's chief field project on his recent visit in Java. Field trips were made as time and opportunity permitted, and numerous local entomologists were consulted on the subject of termites.

There are numerous termite species in Java, among which the following are of major importance:

Calotermes tectonae Damm. This termite attacks only teak. It nests in the trunks of trees usually from twenty to thirty years old, at a height of from 5 to 10 meters above the ground. The formation of the nest causes a gnarled swelling in the trunk, over which the bark cracks. Several of these swellings may occur in a single tree. The various nests may communicate with one another, but are not connected with the ground. Very small holes open to the exterior. Winged individuals are found in the nests just before the rainy monsoon, and swarming takes place when the rains begin. True workers are absent, the nymphs acting as workers. The commercial value of the timber is much reduced by the attacks of this termite, due to the injury to the grain, and to breakage in winds. In some places fully 75 per cent of the trees are attacked. The only control attempted for this pest is thinning out infested trees. This is done in the dry season, before winged adults begin to swarm. The swellings in the trunks are sawed out and burned, because these termites can live for long periods in felled trees. Dr. Kalshoven, of the Instituut voor Plantenziekten at Buitenzorg, has studied the teak termite for several years, and is on the point of publishing his results.

Coptotermes gestroi Wasm. This close relative of the *Coptotermes* occurring in Hawaii, is known from Burma, the Malay Peninsula and the Greater Sunda Islands (Java, Sumatra, Borneo and Celebes). It attacks *Hevea,* kapok, *Ficus,* coconut, mango and various forest trees. The damage to *Hevea* is sometimes severe, especially in the Sumatra rubber plantations, where a closely related species (*C. curvignathus* Holmgren) is the most serious pest of rubber. The damage from *C. gestroi* in Java is said to be comparatively unimportant. Nests are located in and around infested trees, and as with our species, are connected with the ground by means of covered runways. I was unable to see this termite in the field in Java on account of its rarity. Treatment in Sumatra consists of pumping sulfur-arsenic fumes into the nests with a special device, and of burying sawdust mixed with Paris green (100 parts of sawdust to 1 of poison) in the soil about small infested plants. In the Malay Peninsula stress is laid on removing surface timbers, old roots and stumps from the plantations.

Macrotermes gilvus Hagen. This is one of the commonest termites in the Archipelago and is distributed from the Malay Peninsula east to the Celebes and Timor, and north to the Philippine Islands. It builds a low, broad mound and attacks house timbers and dead wood, but not uncommonly feeds in growing sugar cane and in *Manihot* (the tapioca plant). Both in Java and on the island of Luzon the writer was able to observe its work in sugar cane fields. Through the kindness of Dr. R. Brink, group-adviser of the Proefstation voor Suikerindustrie at Pasoeroean, and of Manager van der Haas of Gedaren Plantation near Solo, an inspection was made of the Gedaren fields. Termite damage to cane there was infrequent but some stalks were found which had been killed by this termite's feeding. This occurred on "tegallan" (unirrigated) lands, on fairly light soil, and at Gedaren is said to occur only after the water is shut off from the cane fields for use on the rice "sawahs."

According to Dr. K. W. Dammerman, another, smaller species, *Microtermes jacobsoni* Holmgren, sometimes lives in the upper part of nests of *M. gilvus.*

Natural Enemies

Numerous predators on termites have been recorded from the Malay Archipelago, among them ants, fowls, crows, orioles, starlings, swallows, swifts, lizards, toads, and the scaly ant-eater. Most of these are only occasional feeders which have access to the termites only when some mishap has broken up a nest or a run. Only the ant-eater and one species of ant are known to open up termite structures of their own accord.

Odontoponera transversa Smith is a ground-inhabiting ant, common throughout the Indo-Malayan region. It is capable of breaking open termite runs, from which it bears off the occupants. Wheeler and Chapman say of this ant in the Philippines that "it is especially fond of termites, and is often seen raiding their colonies." Dr. F. X. Williams, who studied this ant at Los Baños, writes as follows: "An unbroken coverway may nevertheless form a fairly effective barrier against *O. transversa,* whose small colonies do not seem equal to the task of holding any of these exceedingly numerous termites in check. When a flight of termites takes place, as was noticed late one afternoon in the case of *Microcerotermes, Odontoponera* captures many winged forms about their carton nests." It is probable that were this ant to be introduced into Hawaii it could not maintain itself against the common *Phidole megacephala* already here.

While at Los Baños in April, I was shown in Dr. Uichanco's laboratory specimens of a muscid fly said to be predaceous on winged termites in flight. These appeared to be identical with *Bengalia latro* de Meij., whose habit of raiding true ants when marching in columns, of their food and young, and whose attacks on flying termites have been noted by the late Dr. Charles F. Baker and by Dr. Williams. Nothing further is known of the habits or biology of this fly, but Fox has recorded the fact that larvae of a species of *Bengalia* occurring in Africa, burrow under the skin of certain mammals, including man, and pupate in the ground.

C. E. Pemberton and D. T. Fullaway having informed the writer of finding

abandoned termite nests in the Dutch East Indies, which contained a certain amount of fungous growth, hopes were cherished of finding a fungus which is parasitic on termites. The examination of termite nests in Macassar (Celebes) and Java failed to reveal any such parasitic fungi. The young of many termite species are fed on the conidia of fungus gardens cultivated within the nest, thus obtaining a food more nitrogenous and easier digested than wood itself. One such fungus, according to Dr. Dammerman, belongs to the genus *Aegerita,* and often assumes a mushroom-like character of growth after the nest has been abandoned. Various termite species cultivate different fungi, and one commonly isolated from fungus-combs in termite nests is *Xylaria.*

Some years ago Dr. J. C. Koningsberger found a fungus, later described as *Cordyceps koningsbergeri* P. and S., which was parasitic on the nymphs of an unnamed termite, and which developed growths resembling grass roots. Dr. S. Leefmans, director of the Plant Disease Institute at Buitenzorg, informed me that this fungus is so rare that it has not been found since its original discovery by Dr. Koningsberger.

Certain species of Phorid flies belonging to the genus *Termitoxenia* are parasitic in the heads of some termites; for example, in a species of *Odontotermes* in Java. Mr. Pemberton some years ago reported such flies in termite heads in the Celebes, but they are rare insects. Their value as parasites is problematical (as in the case of nematodes found in some termite heads), since they apparently produce distortion and not always death in the individual which they attack.

In the Philippines, Dr. F. Silvestri lately found larvae of a Conopid fly similarly parasitic in the heads of soldiers of *Macrotermes gilvus.*

Numerous protozoans have been described from the intestinal tracts of termites, and it was formerly believed that some of them might be parasitic forms. However, recent work has shown that they act as symbionts, aiding the termites in the digestion of the raw cellulose which constitutes their principal food. Experiment has shown that some termite species die in the absence of such intestinal protozoans.

The scaly ant-eater (*Manis javanica* Desm.) or pangolin, a harmless creature, is thus discussed by Dr. Dammerman: "This rather beneficial animal is found throughout southern and southeastern Asia, to the Greater Sunda Islands, Celebes and Palawan in the Philippines. The pangolin conceals itself during the daytime in burrows or in trees, which it ascends with facility. At night it searches for food, which consists of ants and termites, especially of the latter. The termites' nests are broken open with the claws and the inhabitants licked up by the long tongue. . . ."

To sum up: It is the opinion of Dutch zoologists, who have lived with the problem for years, that there is no termite enemy of first-rate importance in the Dutch East Indies. The foregoing notes would indicate that such enemies of termites as are known to occur there cannot be considered valuable enough for introduction into the Hawaiian Islands.

Suggestions on Experimental Technique

By E. E. Naquin

It is a recognized fact that the purpose of an experiment should conform with the principal problems of the plantation involved.

One of the problems which concerns us most in parts of the unirrigated districts is "soil irregularity". On a plantation having, in general, wide variation, perhaps the most valuable experimental layout is one under actual field conditions. The above problem concerns both variety and fertilizer experiments, and the techniques which have to do with experimentation may be discussed under these respective topics.

Variety Experiments

Variety tests as a rule begin with a limited amount of seed cane and preliminary tests usually occupy the time required to accumulate sufficient seed for large size experiments. By that time, providing these early tests were well conducted, the best seedlings should have been selected. These superior canes as a rule must undergo a long period of testing against the standard variety grown locally. By conducting, with the few most promising varieties, large size experiments under general field conditions, much time and labor may be saved.

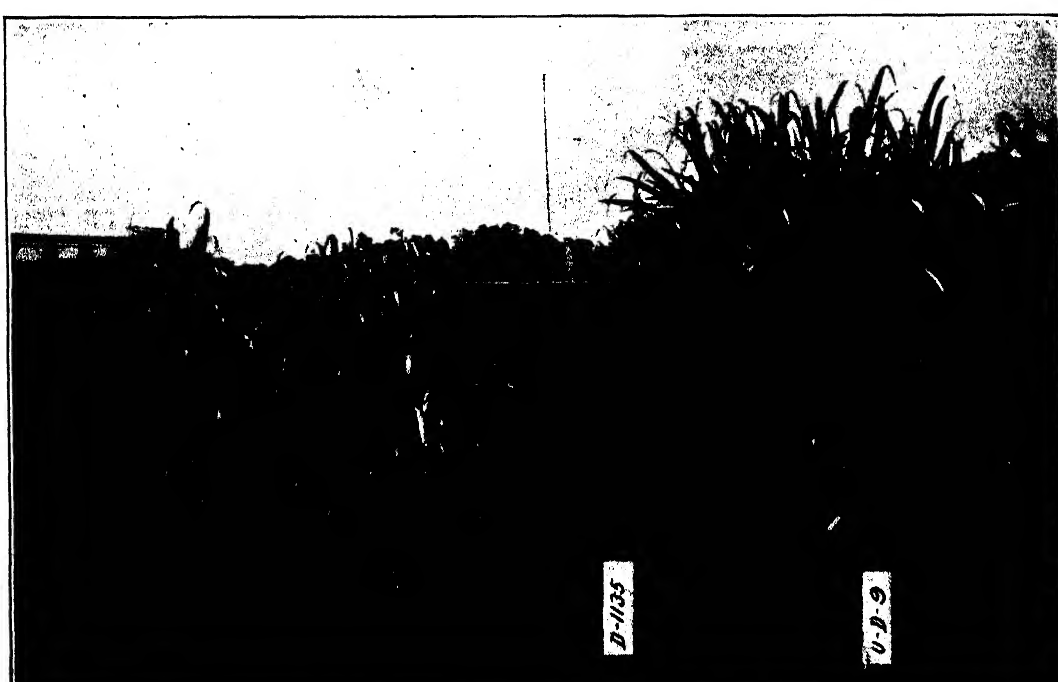


Fig. 1. Showing how the adjacent row of D 1135 has been smothered out, after the second crop, by the more vigorous variety growing alongside of it. The cane was six months old second ratoons.

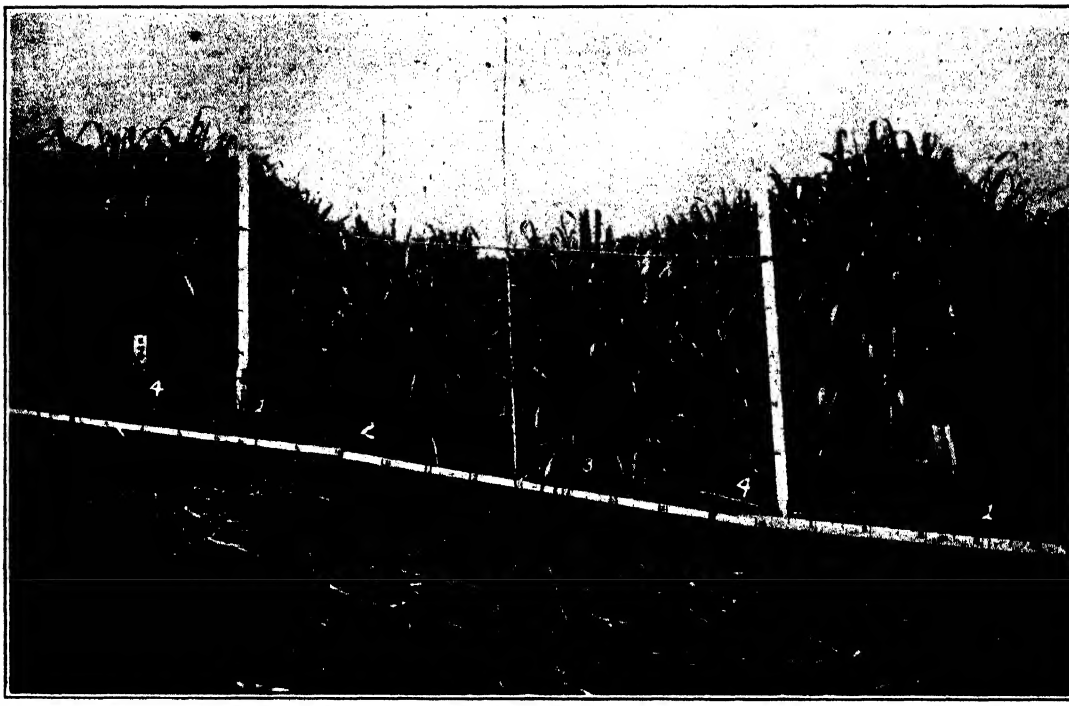
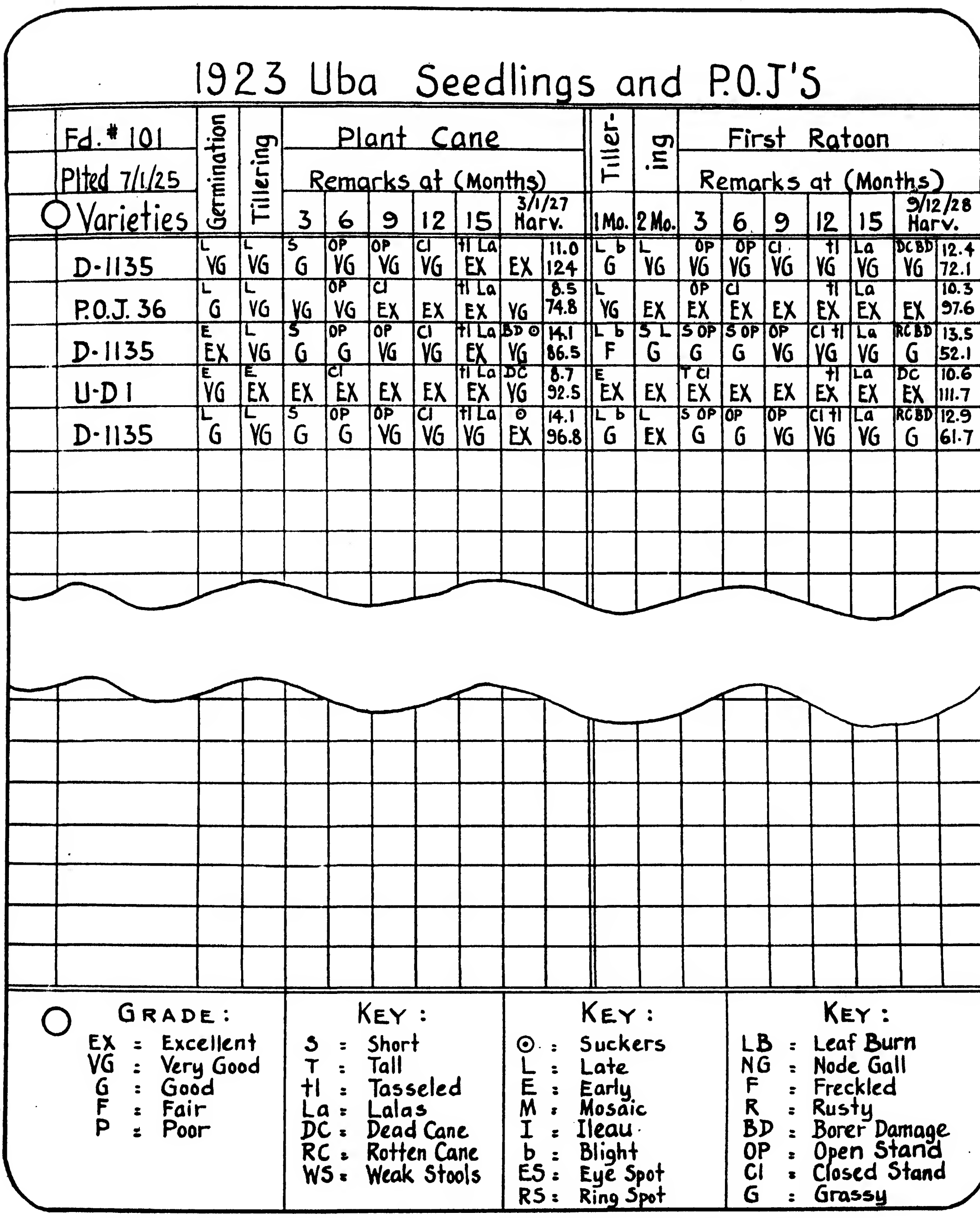


Fig. 2. Showing how a four-line check plot of D 1135 has been reduced to two lines after the second harvesting. The cause was due to the two vigorous growing varieties of different type growing on both sides. The cane was six months old second ratoons.

Fig. 3. Showing the difference in the width and height of the outside rows as compared with the inside rows of cane of a four-line variety plot. Note the smothering effect on the inside rows. The cause is due to the outside rows of the more vigorous variety taking advantage over D 1135 growing in the adjacent plots.



1923 Uba Seedlings and P.O.J'S

Fd. # 101 / Plted 7/1/25 / Varieties	Germination	Tillering	Plant Cane: Remarks at (Months) 3	6	9	12	15	3/1/27 Harv.		Tiller-ing 1 Mo.	2 Mo.	First Ratoon: Remarks at (Months) 3	6	9	12	15	9/12/28 Harv.	
D-1135	L VG	L VG	S G	OP VG	OP VG	Cl VG	tl La EX	EX	11.0 124	L b G	L VG	OP VG	OP VG	Cl VG	tl VG	La VG	DC BD VG	12.4 72.1
P.O.J. 36	L G	L VG	VG	OP VG	Cl EX	EX	tl La EX	VG	8.5 74.8	L VG	EX	OP EX	Cl EX	EX	tl EX	La EX	EX	10.3 97.6
D-1135	E EX	L VG	S G	OP G	OP VG	Cl VG	tl La EX	BD ⊙ VG	14.1 86.5	L b F	S L G	S OP G	S OP G	OP VG	Cl tl VG	La VG	RC BD G	13.5 52.1
U-D 1	E VG	E EX	EX	Cl EX	EX	EX	tl La EX	DC VG	8.7 92.5	E EX	EX	T Cl EX	EX	EX	tl EX	La EX	DC EX	10.6 111.7
D-1135	L G	L VG	S G	OP G	OP VG	Cl VG	tl La VG	⊙ EX	14.1 96.8	L b G	L EX	S OP G	OP G	OP VG	Cl tl VG	La VG	RC BD G	12.9 61.7

GRADE:
- EX : Excellent
- VG : Very Good
- G : Good
- F : Fair
- P : Poor

KEY:
- S : Short
- T : Tall
- tl : Tasseled
- La : Lalas
- DC : Dead Cane
- RC : Rotten Cane
- WS : Weak Stools

KEY:
- ⊙ : Suckers
- L : Late
- E : Early
- M : Mosaic
- I : Ileau
- b : Blight
- ES : Eye Spot
- RS : Ring Spot

KEY:
- LB : Leaf Burn
- NG : Node Gall
- F : Freckled
- R : Rusty
- BD : Borer Damage
- OP : Open Stand
- Cl : Closed Stand
- G : Grassy

Note : The data in the harvesting column represent the quality ratio and tons of cane per acre.

Fig. 4. Showing a condensed field form used for keeping observation data on variety experiments.

Layout: For testing canes under general field conditions at Honokaa the plots usually extend the entire width of the field or field section. When different types of canes are involved, six to ten rows per plot prove best. The effect that one type of cane may have on another growing in adjacent plots is well illustrated in Figs. 1, 2 and 3.

Observation: This phase of a variety test is perhaps more important, in so far as gaining a knowledge of the varieties is concerned, than the final harvesting data. The more one deals with various types of canes having different agricultural qualities, etc., the greater becomes the importance of observation.

Since varieties grow at different rates, growth measurement may be made a useful tool in determining at what time the growth ceases to be economical.

Observation should include everything that has taken place in the variety plots which may affect the commercial value of the varieties. Perhaps the most effective way of carrying out a systematic method of observation is by having fixed dates for periodic calls on each test. One who is conscientious in his work will find one's self keeping these dates in the same manner that one would keep a business appointment. Of course, besides these formal calls there should exist a flexible program for intermediate visits. Fig. 4 shows a condensed field form which has been used at Honokaa with much satisfaction. Such a form becomes more important when there is a large number of seedlings to be observed.

Harvesting: Plots extending across the field lend themselves well in harvesting by the flume system. The flume lines run across the plots so that the cane can be harvested in sections of desirable dimensions, varying from 50 to 200 feet in length. The field test is harvested in the same fashion as that of the field crop so that very little time is lost. All that is required is close supervision of the field men. Filipinos have proven very satisfactory for this purpose, as they can make themselves readily understood by the laborers of their own race, of which the harvesting gangs are largely composed.

If the purpose of the experiment is to study varieties under actual field conditions and in regard to soil variations, it is essential that cane samples for juice analysis be taken accordingly. Since the flume lines run crosswise in the test plots, it is an easy matter to flume car-lot samples from individual plots, packing the cane in the usual way to the sides of the flume. Using a code system with cane top bundles for delivering the necessary signals to the fluming station, and timing of each sample, makes it possible to flume car-lot cane samples at any distance away from the fluming station.

When the experiment consists of a great number of large size plots, fluming all of the cane from individual plots for the purpose of weighing the cane at the mill is impractical. The delay which is then incurred in the fluming is too great. In that case the usual method of weighing every third bundle of cane in the field is resorted to and proves very accurate, particularly when the bundle system of cutting cane is in vogue. Salter's spring scales are used for this purpose.

Results: Bearing in mind that, in this case, irregularity of the soil is the most important problem in selecting a variety, the results should be studied in that respect. Fig. 5 shows a very effective way of interpreting such results.

Comparing D 1135 and Uba in Fig. 5 it is noted that in good soil, Section A,

Uba yielded 59.8 tons of cane per acre against 42.7 tons for D 1135. Uba gave a quality ratio of 21.8 as compared with 9.1 for D 1135. Owing to its poor juice, it yielded only 2.74 tons of sugar against 4.69 for D 1135. In less fertile soil, Section B, Uba yielded 51.2 tons of cane as compared with 43.3 for D 1135. Uba improved in juice quality as shown by the figure 17.9. D 1135 ratio was the same, 9.1. Uba was again a poor yielder in sugar as compared with D 1135, yielding 2.85 tons against 4.76 tons for D 1135. On thin soil, Section C, the quality of the Uba juice was greatly improved. It gave a quality ratio of 10.4 as compared with 8.4 for D 1135. The yield of 57.8 tons of cane for Uba was as much as it yielded on the better soil. D 1135 tonnage dropped, as shown from the figure 25.2. Uba this time yielded 5.55 tons of sugar against 3.00 tons for D 1135.

Comparing the averages of the two canes, we have the following results: Quality ratio, 15.2; tons of cane, 56.2; tons of sugar, 3.70, for Uba as compared with 8.8, 37.1 and 4.22, respectively, for D 1135. The averages pointed out that Uba was unprofitable for the field in general. However, the data in Section C indicates that Uba is profitable for thin-soil areas. U. D. 1 and U. D. 67 may be compared in the same sphere.

Yield in Tons Per Acre

	Section -"A"-			Section - B-			Section -C-			Averages		
Varieties	Q.R.	Cane	Sugar	Q.R.	Cane	Sugar	Q.R.	Cane	Sugar	Q.R.	Cane	Sugar
D-1135	9.1	42.7	4.69	9.1	43.3	4.76	8.4	25.2	3.00	8.8	37.1	4.22
Uba	21.8	59.8	2.74	17.9	51.2	2.85	10.4	57.8	5.55	15.2	56.2	3.70
D-1135	9.8	58.8	6.00	9.8	33.3	3.39	8.1	27.8	3.42	9.8	39.9	4.08
U-D1	11.8	45.9	3.88	11.5	36.8	3.20	8.7	46.8	5.37	10.4	43.1	4.15
D-1135	11.3	63.6	5.62	11.0	30.4	2.76	8.1	20.1	2.48	9.5	38.0	4.00
U-D67	14.4	60.5	4.20	12.7	50.8	4.00	10.5	36.1	3.43	12.5	49.1	3.93
Field Topography	Level			Slope			Slope (Near Top of Knoll)			Averages		

Fig. 5. Showing variety experiment results in relation to the topography of the test plots.

It is seen from these results that one should not depend too much on general averages. It also points out the importance of conducting variety tests under general field conditions.

Fertilizer Experiments

If the purpose of the experiment is to test different forms of nitrogen fertilizers, phosphate or potash forms, it is no doubt best to use a uniform layout where the results may be computed to a fine point. On the other hand, if it is a plant food test or a quantitative test, experiments under general field conditions are perhaps the most valuable to the plantation.

Layout: The plant food ingredients in fertilizer do not react in the same magnitude in the low-lying areas as they do on the knolls and thin-soil areas. Soil variation should therefore be considered when a layout is being selected.

Ten-row plots extending across the field or field section are proving most satisfactory at Honokaa. The danger of having insufficient guard rows adjacent to each plot can best be realized from Figs. 7, 8, 9 and 10. These photographs were taken in each case on the leeward side of the treated plots so that the question of the wind blowing fertilizer on the adjacent rows of the other plot is obliterated. In Fig. 7 the rows are four feet wide and the plots consist of six rows each.

HONOKAA SUGAR CO. FERTILIZER EXPERIMENT
Field 18. Unirrigated Area - 1100 FT. Elevation
Crop 1927 - D1135 - 4th. ratoon

Tons of Cane Per Acre.

Plot	Pounds Plant Food Per Acre	SEC.-A-		SEC.-B-		SEC.-C-		SEC.-D-		AVE.
1	200 Nitrogen		41.4		43.2		39.6		46.2	42.6
2	200 Nit. - 4000 Mill Ash	Hilly and Level	51.7		47.3	High area	44.3	High area	46.6	47.5
3	200 Nitrogen		48.6	Hilly and Level	46.0		51.1		31.2	44.2
4	200 Nit. - 100 K_2O		48.8		45.7		53.3		37.6	46.3
5	200 Nitrogen		38.1		37.0		44.7		33.5	38.3
6	200 Nit. - 100 P_2O_5		34.7		39.0		40.3	Low area	38.7	38.2
7	200 Nitrogen		29.8		42.3	Low area	47.0		48.3	41.8
8	200 Nit. - 100 P_2O_5 - 4000 Mill Ash		36.1		35.6		56.8		60.0	47.1
9	200 Nitrogen		35.8		37.7		45.0		55.9	43.6
10	200 Nit. - 100 K_2O - 100 P_2O_5		29.0		44.7		50.6	Slope	40.6	41.2
11	200 Nitrogen	Hilly and Low	30.5	Low area	40.2		45.2		43.0	39.7
12	200 Nit. - 8000 Mill Ash		49.2		47.3		46.9		43.0	46.6
13	200 Nitrogen		33.4		40.9	High area	35.8	High area	40.6	37.7
14	200 Nit. - 200 K_2O		47.8		51.0		38.3		42.8	44.9
15	200 Nitrogen		29.7		36.2		36.7		41.6	36.0
16	200 Nit. - 200 P_2O_5		36.1		37.2		46.2		43.6	40.8
17	200 Nitrogen		34.1	High area	32.4		47.6		30.8	36.2
18	200 Nit. - 200 P_2O_5 - 8000 Mill Ash		52.7		37.1	Low area	48.7	Low area	44.5	45.7
19	200 Nitrogen	High	23.5		38.9		41.9		40.0	36.1
20	200 Nit. - 200 K_2O - 200 P_2O_5		26.8		40.1		53.8		48.9	42.4
21	200 Nitrogen		17.6		46.5		39.1		41.6	36.2

A B C D AVE.

Field Topography

Fig. 6. Showing the yield of cane per acre, of a fertilizer experiment, in relation to the field topography.

Fig. 7. Showing how the cane in a "no nitrogen" plot was affected by the nitrogen from the adjacent plot. Note the difference in growth, in the no nitrogen plot, of the cane in the two rows next to the check plot as compared with the third row. The difference in the color of the foliage was also very marked. Plot 7 received 186 pounds of nitrogen per acre, plot 8 had no fertilizer. The cane was ten months old D 1135 ratoons.

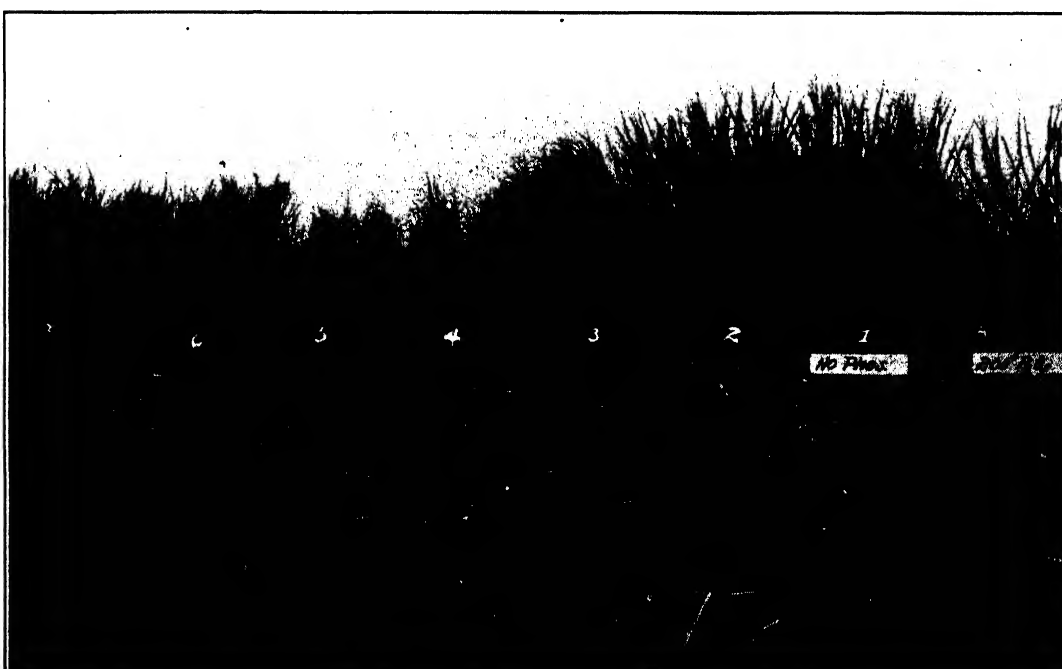


Fig. 8. Showing how the cane in a "no phosphate" plot was affected by the phosphate applied on the adjacent plot. Note the difference in growth, in the "no phosphate" plot, of the two rows of cane next to the 200-pound P_2O_5 plot as compared with the third, fourth and fifth rows. Both plots received equal amounts of nitrogen. The cane was twenty-four months old plant Uba.

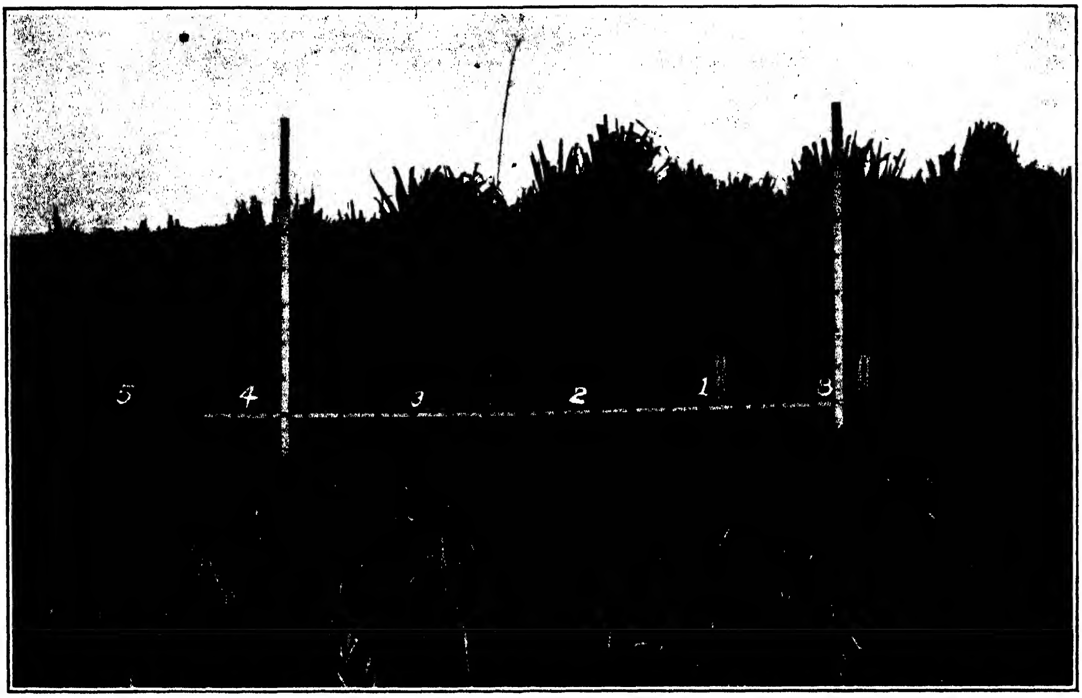


Fig. 9. Showing how the cane in a check plot was affected by the potash applied on the adjacent plot. Note the difference in growth of the three rows of cane next to the 100-pound K_2O plot as compared with the fourth and fifth rows. Both plots received equal amounts of nitrogen. The cane was ten months old D 1135 ratoons.

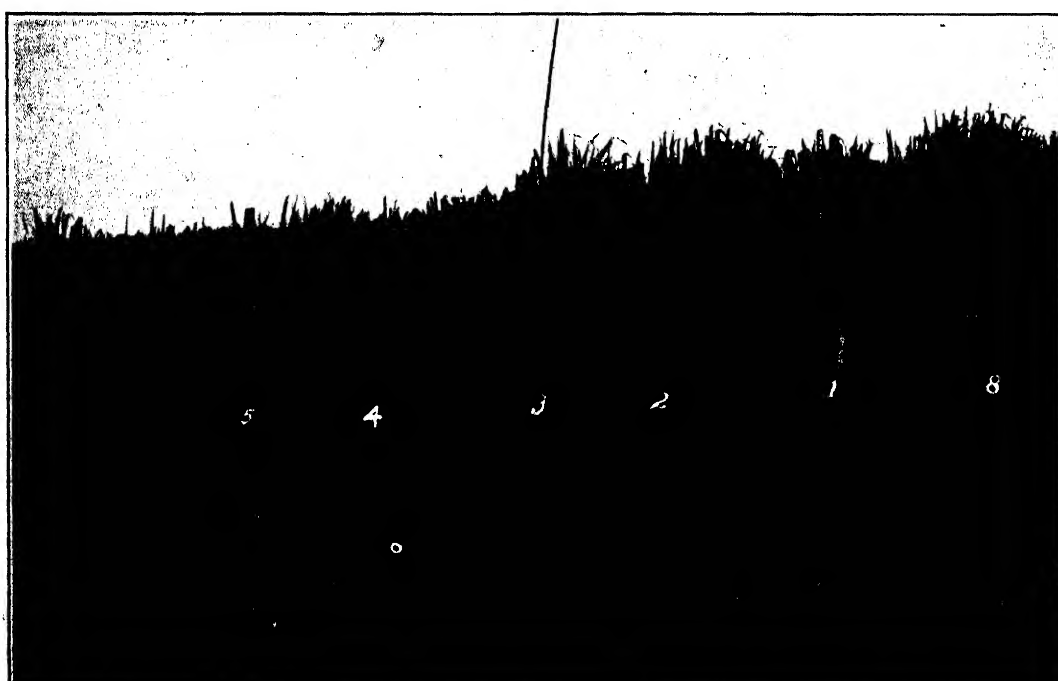


Fig. 10. Showing how the cane in a check plot was affected by the phosphate and potash applied on the adjacent plot. Note the difference in growth of the three rows of cane next to the 100-pound P_2O_5 and 100-pound K_2O plots as compared with the fourth and fifth rows. Both plots received equal amounts of nitrogen. The cane was ten months old D 1135 ratoons.

In Figs. 8, 9 and 10 the rows are four feet wide and the plots consist of eight rows each.

If such conditions as shown in Figs. 7, 8, 9 and 10 exist in fertilizer experiments under dry, unirrigated conditions, one wonders what happens to experiments which are subject to frequent irrigation and rainfall.

Observation: Observation in fertilizer tests, as a rule, is somewhat more elastic than that for variety tests. Much has been attained here at Honokaa by carefully examining fertilizer plots every three months, and by keeping notes in regard to the general appearance of one plot as compared with another, as well as the general appearance of the cane in each plot. A thorough examination of the plots at harvest also yields valuable information that is often not registered in the final figures. Growth measurements, borer and dead-cane counts, estimating the percentage of large- and small-size sticks and examining the root system all help in familiarizing one with the condition of the cane in the individual plots.

Harvesting: From the photographs in Figs. 7, 8, 9 and 10 it is obvious that the proper number of rows serving as guards on both sides of the plots should be omitted from the final results. The harvesting proceeds in the same manner as described under variety experiments. If the amount of plots is not too numerous, it is possible to take car-lot cane samples for juice analysis. If the number of plots prohibits this method, the next most satisfactory way is to take eight cane bundle samples from each plot.

Results: Bearing in mind that the experiment is to test fertilizer under general field conditions, the final results should be interpreted in that respect. This can best be illustrated from the data as shown in Fig. 6.

Taking the figures from plots 13, 14 and 15 in Fig. 6 as an example, it is noted that the treatment of 200 pounds of K_2O as compared with no potash gave, in Section A, 47.8 tons of cane per acre against 33.4 and 29.7 tons for the check plots. In Section B the same treatment gave 51.0 tons as compared with 40.9 and 36.2 tons for the check plots. In Section C the treated plot showed a tonnage of 38.3 against 35.8 and 36.7 for the checks, and in Section D 42.8 tons as compared with 40.6 and 41.6 tons for the checks. It is noted from the topography lines a, b, c and d that the two sections, A and B, giving the large gains in favor of the treatment, were in low-lying areas, while the other two, C and D, giving small gains, were on high areas.

It is further noted that the treated plot gave an average yield of 44.9 tons against 37.7 and 36.0 tons for the checks, or a gain of 8 tons of cane in favor of the treatment. The gains for Sections A, B, C and D were 16.3, 12.5, 2.1 and 1.7 tons, respectively. It is clearly seen from these figures that the general average does not reveal the true status of the results. The other plots may be compared in the same manner.

Fig. 6 shows the lay of the land crosswise of the plots only. As part of the detailed information in field tests, the topography of the areas is sketched lengthwise of the plots as well. With the proper lay of the land charted, one can compare to better advantage the juice qualities and sugar yields as well as the cane yields.

Bud Selection

WAIPIO SECTION 27

By J. A. Verret

Bud selection work was started here in 1920. For several years the work was under the supervision of A. D. Shamel, of the U. S. Department of Agriculture, stationed at Riverside, California, and engaged in citrus improvement by means of bud selection. Mr. Shamel made yearly visits of several months duration to the Islands for several years.

In 1927, all yield figures which had been obtained on the various H 109 progenies from the beginning of the bud selection work up to that time, were assembled and the progenies were graded according to their performance.

A test with as many repetitions as the available seed permitted was planned. Every other plot was planted with unselected H 109 seed. The area was laid out in carload-sized plots. Three progenies among the best and three among the progenies having made the poorest showing were included in this test. In addition, seven progenies were included which had been observed by W. W. G. Moir and others to be above or below the average of H 109 crop cane.

The progenies included in this test and their rating at the time are listed below:

P 172	10 plots	Good in previous tests
P 68	"	"
P 63	"	"
P 142	1 plot	Poor in previous tests
P 153	"	"
P 155	"	"
Dwarf 2456	10 plots	Said to be poor
Type 2	"	"
Type 1	"	Good in previous tests
Type 5	"	"
PM 204	3 plots	Selected by Mr. Moir as good
B 5 516	"	"
B 5 529	"	"

Progenies 172, 68, 63, 142, 153 and 155 were selected at Waipio in 1920. At the time of selection none of these were selected as poor types.

Types 1, 2, 5, PM 204, B5-516 and B5-529 were selected by Mr. Moir on Maui. Type 2 was considered poor at the time of selection. Dwarf 2456 was selected at Paauhau by the plantation authorities and was poor from the beginning, although it originated from a large stool of H 109.

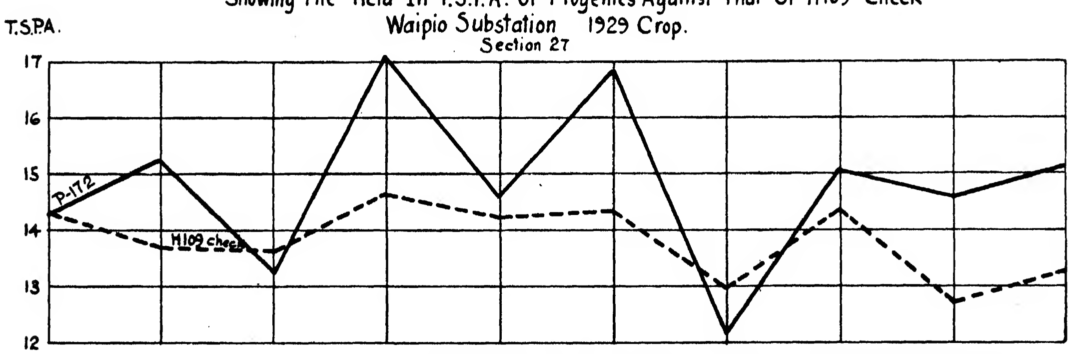
The test was planted June 8-12, 1927, and harvested in April, 1929, at 22 months of age.

The results of the harvest are:

Progeny	Rating When Planted	No. of Plots	T. C. P. A.	T. S. P. A.	Per Cent Gain or Loss Over Check
172	Good	10	107.9	14.82	+ 7.2
Check		34	102.5	13.82	
68	Good	10	108.8	14.53	+ 4.2
Check		31	103.9	13.94	
63	Good	10	107.1	14.55	+ 3.8
Check		29	103.9	14.01	
Type 1	Good	10	104.7	14.20	+ 2.4
Check		31	103.0	13.86	
Type 5	Good	10	101.1	13.56	± .0
Check		28	99.5	13.58	
Type 2	Poor	10	104.1	13.83	+ 0.8
Check		28	101.2	13.71	
Dwarf 2456	Poor	10	100.0	13.47	— 3.2
Check		29	104.3	13.91	
PM 204*	Good	3	91.2	11.40	— 5.8
Check		8	95.9	12.06	
B5-516	Good	3	95.7	12.55	— 0.9
Check		7	96.7	12.66	
B5-529	Good	3	94.8	12.55	+ 2.4
Check		7	94.6	12.25	
P 142	Poor	1	103.6	13.39	— 0.3
Check		3	102.2	13.43	
P 153	Poor	1	93.8	11.95	— 0.9
Check		3	94.8	12.06	
P 155	Poor	1	87.8	10.75	—14.5
Check		3	94.9	12.57	

* One plot of PM 204 gave a yield of only 69 tons cane, much below any other plot in the test. Discarding that plot, the yields are: Cane 101.3 tons and sugar 13.1.

Showing The Yield In T.S.P.A. Of Progenies Against That Of H109 Check
Waipio Substation 1929 Crop.
Section 27



Note: P-172 the best among progenies Student's odds 81 to 1

Note: P-68 the second best. Student's odds 73 to 1

Fig. 1

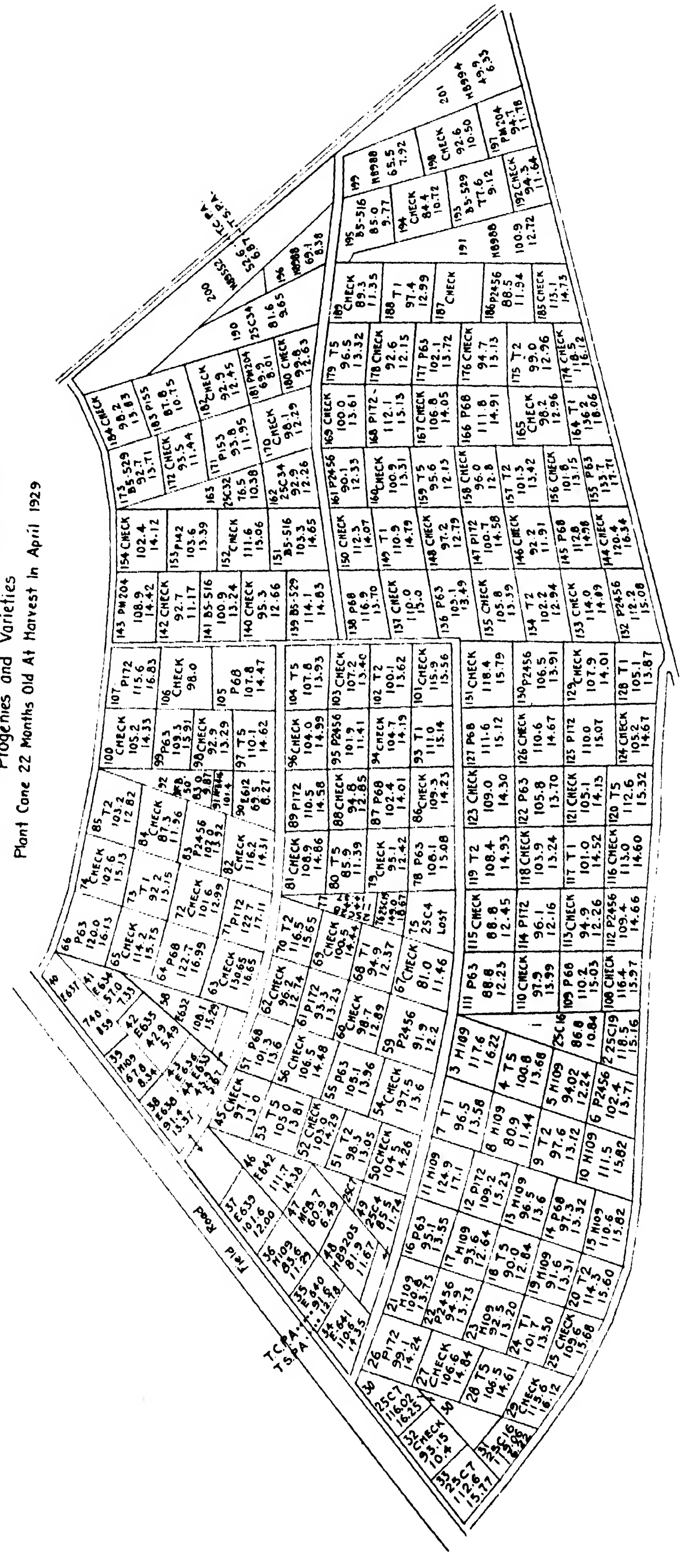

WAIPIO SUBSTATION SECTION 27 1929 CROP
Progenies and Varieties
Plant Cane 22 Months Old At Harvest In April 1929

Fig. 2

Two of the progenies in the test are especially promising, having consistently outyielded H 109 in ten plot replications. These are Progeny 172 and Progeny 68. The plot yields of these two progenies with their unselected H 109 check plots are shown by means of graphs in Fig. 1.

A mathematical interpretation of these results by means of Student's Method gave odds of 81 to 1 that the gain of one ton of sugar of Progeny 172 over its checks was not due to chance. Progeny 68 was next with odds of 73 to 1. Progeny 63 also compared well.

Dwarf Progeny 2456, in accordance with its previous record, was poorer than its adjoining checks.

As a whole, these progenies behaved consistently with their previous records, indicating that the differences are inherent.

In Fig. 2 a map of the layout is shown with the yield of each plot.

Detailed Summary

Object: Bud selection and variety test.

Crop: H 109 and varieties, plant cane 22 months old.

Location: Waipio Substation Section 27.

Layout: Irregular size plots of about 6 lines each. Cane weights and juice samples taken at the mill of the Oahu Sugar Company.

Fertilization: Uniform to all plots.

August, 1927	October, 1927	February, 1928	Total N	Total P_2O_5	Total K_2O
951.7 CF	488 AS	617.7 AS	302	75	75

P-172

Plot No.	P 172 T.C.P.A.	P 172 T.S.P.A.	Plot Check Nos.	Check T.C.P.A.	Check T.S.P.A.	Gain of A Over B	d	d^2
26	99.13	14.24	27–21	103.7	14.30	— .06	+1.06	1.12
12	109.20	15.23	11–17–13–8	98.9	13.69	+1.54	— .54	.29
61	93.30	13.23	62–56–60–69	100.5	13.64	— .41	+1.41	1.99
71	122.7	17.11	63–72–82	116.1	14.65	+2.45	—1.45	2.10
89	110.5	14.58	81–96–88	102.6	14.23	+ .35	+ .65	.42
107	115.6	16.83	100–106	101.6	14.33	+2.50	—1.50	2.25
114	96.1	12.16	110–115–113–118	96.4	12.98	— .82	+1.82	3.31
125	110.0	15.07	121–129–126–124	107.2	14.37	+ .70	+ .30	.09
147	110.7	14.58	135–158–148–146	97.8	12.72	+1.86	— .86	.74
168	112.1	15.13	160–179–169–167	100.1	13.28	+1.85	— .85	.72
Avg.	107.9	14.82		102.5	13.82	9.96		13.03
					Mean	1.00		1.30

S. D. $= \sqrt{1.30}$

$= 1.14$

$$Z = \frac{1.00}{1.14} = .9$$

Odds 81 to 1

P-68

Plot No.	P 68 T.C.P.A.	P 68 T.S.P.A.	Plot Check Nos.	Check T.C.P.A.	Check T.S.P.A.	Gain of A Over B	d	d^2
14	97.3	13.22	13–15–10–19	99.6	14.18	— .96	—1.65	2.72
57	101.3	13.60	45–56–52	99.93	13.41	+ .19	.50	.25
64	122.7	16.99	63–65–72	115.5	15.13	+1.86	+1.17	1.36
87	102.4	14.01	79–86–88–94	101.9	13.42	+ .59	— .1	— .01
105	107.8	14.47	98	92.8	13.29	+1.18	.49	.24
109	110.2	15.03	108–110–113	103.1	14.07	+ .96	.27	.07
127	111.6	15.12	125–126–131	112.7	14.92	+ .20	— .49	.24
138	116.9	13.70	137–150	111.1	13.53	+ .17	+ .52	.27
145	112.8	14.98	133–144–146–156	107.1	13.87	+1.10	.41	.17
166	111.8	14.91	158–165–167–176	98.9	13.26	+1.65	.96	.92
Avg.	108.8	14.53		103.9	13.94			
					Mean	+ .69		

S. D. = $\sqrt{.625}$
= .78

$$Z = \frac{.69}{.78} = .885$$

Odds 73 to 1

P-63

Plot No.	P 63 T.C.P.A.	P 63 T.S.P.A.	Plot Check Nos.	Check T.C.P.A.	Check T.S.P.A.	Gain of A Over B	d	d^2
16	95.11	13.55	11–17–21	106.4	14.50	— .95	+1.49	2.22
55	105.1	13.96	60–56–52–54–65–74	101.4	13.81	+ .15	+ .39	.15
66	120.0	16.13		108.4	15.44	+ .69	— .15	.03
78	108.1	15.08	86–79	102.2	13.32	+1.76	—1.22	1.49
99	109.3	15.91	98–106–100	98.7	13.86	+2.05	—1.51	2.28
111	88.8	12.23	110–115–3	101.4	14.19	—1.86	+2.40	5.76
122	105.8	13.70	123–126–121–118	107.1	14.08	— .38	+ .92	.85
136	103.1	13.49	135–137–148–144–156	104.7	13.06	+ .43	+ .11	.01
155	133.7	17.71		111.1	14.75	+2.94	—2.40	5.76
177	102.1	13.72	167–178–176	98.0	13.11	+ .61	— .07	.05
Avg.	107.1	14.55		103.9	14.01	+5.44		18.60
					Mean	+ .54		1.86

S. D. = $\sqrt{1.86}$
= 1.36

$$Z = \frac{.54}{1.36} = .29$$

Odds 4.11 to 1

T 1

Plot No.	T 1 T.C.P.A.	T.S.P.A.	Plot Check Nos.	Check T.C.P.A.	T.S.P.A.	Gain of A Over B	d	d²
7	96.5	13.58	3–8–11	107.8	14.93	—1.35	—1.69	2.86
24	101.7	13.50	19–23–25–29	102.4	14.58	—1.08	—1.42	2.01
68	94.9	12.37	60–67–69	93.4	12.93	— .65	— .90	.81
73	92.2	13.15	65–72–74–84	101.4	13.98	— .83	—1.16	1.37
93	111.0	15.14	84–94–101	109.9	14.66	+ .48	.14	.02
188	94.4	12.99	178–189	90.9	11.75	+1.24	.90	.81
149	110.9	14.79	137–148–150–160	105.1	13.29	+1.50	1.16	1.35
164	136.2	18.06	165–174	108.3	14.54	+3.52	3.18	10.11
117	101.0	14.52	118–116–113–121	104.2	13.56	+ .96	.62	.38
128	105.1	13.87	124–129	106.5	14.34	— .47	— .81	.66
Avg.	104.7	14.20		103.0	13.86	+3.41		20.38
					Mean	.34		2.04

S. D. $= \sqrt{2.04}$
$= 1.43$

$$Z = \frac{.34}{1.43} = .24$$

Odds 3.1 to 1

T 2

Plot No.	T 2 T.C.P.A.	T.S.P.A.	Plot Check Nos.	Check T.C.P.A.	T.S.P.A.	Gain of A Over B	d	d²
9	96.60	13.12	8–5–10–13	95.8	13.28	— .16	0.27	.0729
20	114.32	15.60	25–15–19	103.9	14.94	.66	— .55	.3025
51	98.3	13.05	50–52	103.8	14.25	—1.23	1.34	1.7956
70	116.5	15.85	62–69	98.9	13.59	2.26	—2.15	4.6225
85	103.2	12.82	74–84	94.9	13.55	— .73	.84	.7056
102	100.1	13.62	94–101–103	109.2	14.38	— .76	.87	.7569
157	101.3	13.42	146–156–158	95.0	12.62	.80	— .69	.4761
175	99.0	12.96	165–174–176	105.7	14.07	—1.11	1.22	1.4884
119	108.4	14.93	115–118–123	100.6	13.33	1.60	—1.49	2.2201
134	102.2	12.94	133–135–146	104.0	13.13	— .19	.30	.09
Avg.	104.1	13.83		101.2	13.71	1.14		12.6305
					Mean	.11		1.26

S. D. $= \sqrt{1.26}$
$= 1.12$

$$Z = \frac{.11}{1.12} = .098$$

Odds 1.59 to 1

T 5

Plot No.	T 5 T.C.P.A.	T.S.P.A.	Plot Check Nos.	Check T.C.P.A.	T.S.P.A.	Gain of A Over B	d	d^2
4	100.8	13.68	3–5–8	97.5	12.66	—1.02	+1.03	1.06
18	90.0	12.84	17–13–19–23	93.6	13.19	+ .35	— .34	.12
28	106.50	14.61	23–29–27	104.9	14.72	+ .11	— .10	.01
53	105.0	13.91	56–45–52	102.2	13.92	+ .01	.....	....
97	110.1	14.62	98	92.9	13.29	—1.33	+1.34	1.80
104	107.8	13.93	96–103	105.6	14.20	+ .27	— .26	.07
179	96.5	13.22	169–189–178	93.9	12.37	— .85	+ .86	.74
159	95.6	12.13	148–167–160–158	100.2	13.24	+1.11	—1.10	1.21
120	112.6	15.32	116–121–113	104.3	14.43	— .89	+ .90	.81
80	85.9	11.39	81–88–79	99.6	13.75	+2.36	—2.35	5.52
Avg.	101.1	13.56		99.5	13.58	.12		11.34
					Mean	.01		1.13

S. D. = $\sqrt{1.13}$
= 1.06

$$Z = \frac{.01}{1.06} = .008$$

No odds

P-2456

Plot No.	P 2456 T.C.P.A.	T.S.P.A.	Plot Check Nos.	Check T.C.P.A.	T.S.P.A.	Gain of A Over B	d	d^2
6	102.40	13.71	5–10	102.7	14.03	+ .32	.12	.01
22	94.9	13.73	17–21–23–27	98.36	13.60	— .13	.15	.02
59	91.90	12.20	54–60–67	92.4	12.65	+ .45	— .01	....
83	102.0	13.92	72–82–84	101.7	13.09	— .83	1.27	1.61
95	101.9	11.41	88–103–94–96	102.7	13.86	+2.45	—2.01	4.04
112	109.4	14.66	113–116–108	108.0	14.27	— .39	.83	.69
130	106.5	15.79	126–129–131	112.3	14.82	— .97	1.41	1.99
132	112.2	15.00	144–133	117.0	15.22	+ .22	.22	.05
161	90.1	12.33	150–160–169	104.4	13.66	+1.33	— .89	.79
186	88.5	11.94	176–185	103.9	13.93	+1.99	— .55	2.40
Avg.	100.0	13.47		104.3	13.91	+4.44		11.60
					Mean	.44		1.16

S. D. = $\sqrt{1.16}$
= 1.07

$$Z = \frac{.44}{1.07} = .41$$

Odds 6.67 to 1 in favor of check

PROGENIES PM 204, B5-516, B5-529, P 142, P 153 AND P 155

Progeny	Plot No.	T.C.P.A.	T.S.P.A.	Check Plot Nos.	T.C.P.A.	T.S.P.A.
PM 204	143	108.9	14.42	154–142	97.5	12.64
PM 204	181	69.9	8.01	182–170–180	96.9	12.46
PM 204	197	94.7	11.78	192–198	93.4	11.07
B5-516	141	100.0	13.24	142–140–153	99.9	12.96
B5-516	151	103.3	14.65	140–152	103.4	13.86
B5-516	195	85.0	9.77	189–194	86.8	11.03
B5-529	139	114.1	14.83	140	95.3	12.66
B5-529	173	92.7	13.71	172–184–154	98.0	13.13
B5-529	193	77.6	9.12	194–198–193	90.4	10.95
P 142	153	103.6	13.39	154–142–152	102.2	13.45
P 153	171	93.8	11.95	172–182–170	94.8	12.06
P 153	183	87.8	10.75	184–172–182	94.9	12.57

The Mitscherlich Method of Soil Testing and Interpretation of Results

By W. J. Hartung

Introduction

The name of Mitscherlich is invariably associated with The Law of Diminishing Returns. As a matter of fact, to those working in the realm of soil and plants, the contribution of vital interest made by Mitscherlich is soil testing by physiological means. It is a quantitative soil analysis, just as is a well-planned, carefully conducted field experiment, with the plant as analyst.

Journals and periodicals, scientific and otherwise, in the English language, contain many references to Mitscherlich, which deal with his "Wirkungsgesetz der Wachstumsfactoren"; few however, have taken the trouble to pry into the long years of painstaking labor. Countless experiments carefully carried out, furnish the foundation for the promulgation of the law stated above.

It is with the idea of bringing to the attention of investigators of soil and plants the methods pursued by Mitscherlich in his determination of the fertilizer requirement of the soil and the interpretation of these pot experiment results in terms of field practice that this brief article has been prepared.

Taking of Soil Sample

After the crop has been harvested and a knowledge of soil requirement for succeeding crops is desired, proceed with sampling as follows:

Drive across the field at about 75 to 80 feet from the border and parallel thereto, using a vehicle with well cleaned body or bed. Toss into this truck or wagon bed at 150-foot intervals a spade full of soil, penetrating surface soil to a depth of about 5 to 6 inches. Arrived at the end of the field, return, keeping parallel to the original course and at a distance of about 150 feet therefrom. Continue this procedure until the whole field has been sampled.

A total of 150 to 200 individual samples should have been taken, depending of course upon the size of the area samples. (*Caution:* Samples should not be taken when soil is wet to stickiness.) The soil is screened through an ordinary gravel screen, and after several thorough mixings by use of shovels, approximately 250 pounds are placed in clean sacks (avoid fertilizer sacks). If soil is too wet for shipment it should be permitted to air dry, care being taken that drying is natural, and that no dog or animal excrements be deposited thereon or in. After soil has been placed in sacks it is ready for shipment to the experimental laboratory.

Installation of the Pot Experiment

Twenty Mitscherlich enameled pots, well cleaned, of a size suitable for cereals, are brought to the same tare by introduction of pieces of quartz rock. Thus all pots, exclusive of soil, weigh exactly alike. The soil is screened through a 1 cm.

sieve and again well mixed by shovel. A sample of soil is taken for soil moisture determinations. The soil should have a moisture content equivalent to that present when soil is in its best physical and mechanical state, neither too wet nor too dry. Each of eight of the prepared pots is now ready to receive its portion of soil. Four of the pots receive soil plus a complete fertilizer. Each portion of soil is carefully weighed out (6 kg.). This is placed in a large mixing pan and in this particular test, for example, the following quantities of fertilizing ingredients were added thus per pot (4 replications):

6 KG OF SOIL

P_2O_5—6 gm. of Thomas Slag	19.4 dz/ha
K_2O—3 gm. of Potash Sulphate	9.7 dz/ha
N—5 gm. of Ammonium Sulphate	16.25 dz/ha

NOTE.—Equivalent in nitrogen in the form of ammonium nitrate or urea may be used.

Each batch is thoroughly mixed by hand in the mixing dish provided. The well mixed soil is transferred to the tared pot, care being taken that the first layer of about 5 cm. in thickness is firmly pressed against the bottom, thereby filling the holes, thus allowing no soil to fall through; furthermore, the remaining soil must be filled in rather loosely yet packed so that soil surface is about 2 cm. below the level of the upper edge of the pot. *Caution:* Be sure to wash mixing dish and hands thoroughly between potting differently treated soils as the fertilizer adhering will affect results of the subsequent potting.

Liming of soil is not necessary if the water used for irrigation contains .03 gram of calcium per liter. On the other hand, .5 gram of sodium chloride is added to each pot to insure the highest action from potash. All constituents added must be carefully weighed, accuracy to 1 per cent being desired. Water soluble ingredients are best added in solution, when upon mixing by hand with some additional water a very satisfactory product results. The pot on being filled is numbered and set aside. Failure to properly number and otherwise designate each container promptly, distinctly and permanently, often leads to experimental errors which can not be rectified subsequently. The exact weight of each pot is then determined. The four other pots also receive equal quantities of soil and fertilizer with exception of nitrogen, none being added.

The remaining pots provide three groups of four pots each, each group to receive but one-sixth the amount of soil employed in groups 1 and 2. Thus a pot will contain 1 kg. of the soil under test and 5 kg. of clean sand, quartz preferably, the available potash and phosphoric acid of which is already known or is to be determined concurrently. Thus the four pots, group 3, will contain 1 kg. of soil, 5 kg. sand and a complete fertilizer of exactly the same composition as that added to soil in group 1.

The four pots of group 4 will receive the same mixture as group 3 minus, however, the potash salt, and the four pots constituting group 5 will each contain the same mixture of soil, sand and fertilizing ingredients as group 3 minus the phosphoric acid constituent.

Following the same procedure and observing the same caution given above, the different portions are mixed, and after placing a piece of gauze over the bot-

tom of the pots to prevent the sand from passing through the holes, each pot is filled and notations are made in a manner as stated above. These twenty pots are quite sufficient for a determination of the supplies of the three chief plant nutrients in a soil. *Note:* Mitscherlich advises that fertilizers of neutral reaction be utilized.

The pots are now ready for planting. A circular board of a diameter a trifle less than the inside diameter of the pot, fitted with twenty-five short pegs—.5 cm. in diameter and 1.5 cm. in length and spaced 3 cm. x 3 cm.—is pressed, pegs downward, into the soil and carefully withdrawn leaving twenty-five holes uniform in every respect. Oats of same strain, from the same field, and preferably from the same harvest should be employed. The oat plant is used as the indicator because it requires relatively little space for growth, because it has a short growing period from seed to maturity, because there is certainty as to yield and heavy yield at that, and because it is but little subject to diseases. Two seeds are placed in each small hole and loosely covered with soil. At the end of fourteen days all seeds should have sprouted, whereupon the stands are thinned down to thirty-five plants per pot.

Setting the pots so that the factors light and heat may be uniform to all is a difficult matter. There has been a contrivance constructed which rests on a small truck. It consists of a standard upright in the center of the truck to which are attached four arms, each capable of holding one pot. This arrangement permits of moving the pots about so that all may have an equal amount of light and warmth.

The matter presenting the greatest of difficulties is that of regulation of soil moisture. The supply of soil water must be kept constant. As long as plants are small and little difference exists between the different pots a constant moisture content may be maintained through regular weighings. Since all pots have the same weight as to tare and all have equal weights of soil, the water content of each may be arrived at through calculation, the soil moisture having been determined on potting.

While the seeds are still sprouting, a light sprinkling will suffice. However, as soon as the plants begin to draw on the soil water, it becomes imperative that the moisture content of all pots be brought to a constant. This may be accomplished as follows: Immediately on removal of excess of plants, the pot is placed on a scale and an amount of water is added which is equal to 50 per cent of the quantity of water the soil is capable of retaining at, viz., its water-holding capacity. Thus the gross weight of the pot equals tare + soil weighed in + 50 per cent of the water required to bring the particular soil to its maximum water-holding capacity. For a time, at weekly intervals, the pots are weighed and water added. Very soon this work must be done every other day, then daily, adding 15 per cent of the water-holding capacity so that at the time the grain is ready to head out, full water-holding capacity has been attained. It is now imperative that this moisture content be maintained. Since the plants in some of the pots are now larger and quite considerably heavier than those of other pots, constant uniform water content cannot be regulated through weighings. The scale is set aside and water is added until it runs out through the bottom. This water is easily returned to the pot since it is caught in the tray fitted to the bottom, thus none of the fertilizing ingredients are lost. This manner of application of water is continued

until within a short time before the date of harvest, when less and less water is required, in fact during the last week very little water need be added, possibly none.

To shield the growing oats from wind damage, wire frames so constructed as to hold the stalks close together are attached to each pot at about the time the grain is ready to head. The harvest from each pot must be removed with the greatest of care. The grain is first carefully stripped from the stalk while stalks and roots are still intact. It is placed in a flask and labeled to correspond with the pot number. The stalks are then cut close to the soil by means of shears, and both grain and straw are dried at 100° C., weighed and yields recorded in grams. These results are later converted to units of weight per hectare; thus, double zentner (dz.) per hectare (ha.). 1 dz. — 100 kg. or 220.4 lbs; 1 ha. — 10,000 sq. meters or 2.471 acres. To avoid confusion in this discussion, we shall throughout use the (dz.) as the unit of weight, and the (ha.) as the unit of area. Let it now be assumed that the results secured from our oat test are as follows:

	Grain and Straw
Average of 4 pots group 1—Soil + N, K, and P (N as Ammonium Sulphate, amount 5 grams)	125.8 ± 1.1 gm.
Average of 4 pots group 2—Soil + K and P	20.4 ± 0.6 gm.
Average of 4 pots group 3—1/6 Soil + 5/6 Sand + N, K and P	113.0 ± 1.5 gm.
Average of 4 pots group 4—1/6 Soil + 5/6 Sand + N and P	90.7 ± 1.2 gm.
Average of 4 pots group 5—1/6 Soil + 5/6 Sand + N and K	66.0 ± 0.8 gm.

Converting yields of groups 1 and 2 to dz/ha we arrive at these values:

	Grain and Straw
Group 1—Soil + N, K and P (16.25 dz/ha Sulphate of Ammonia)	408.9 ± 3.6 dz/ha
Group 2—Soil + K and P	66.3 ± 2.0 dz/ha

The yields resulting from complete fertilization are enormous, in fact Mitscherlich is quite agreed that they are unattainable under field conditions, whereas the yield from the same soil with nitrogen eliminated is so very much less, that the difference between the two yields is decidedly not anywhere near the differences which may be encountered under field conditions. It is just these particularly wide differences which provide the means for a more accurate determination of plant food requirement by pot method over the field. Thus the probable error in pot work when dealing with yields will indicate significant differences, whereas yields from similarly treated plots under field conditions differ so slightly that the probable error reveals nothing tangible.

Calculation

Having converted the yields—variable nitrogen—to units in area and weight, the first step is to find the "Höchstertrag A" as Mitscherlich prefers to designate the highest yield attainable. The formula for this purpose arrived at through experimental means and higher mathematics is finally reduced to the expression $A = \frac{Ky - y^{o}}{K - 1}$ where K is the antilog of c times x; c being the action factor

(Wirkungswert) of ammonium sulphate which has been established experimentally at .025, and x being the unit application of ammonium sulphate, in this case (16.25 dz/ha); y is the yield secured on application of the unit (16.25 dz/ha) of ammonium sulphate; and y^0 is the yield secured when nitrogen is omitted from the fertilization. Substituting

$$A = \frac{(2.549 \times 408.9) - 66.3}{1.549}$$ or 629.9 dz/ha the highest yield attainable.

Then $(66.3 \times 100) \div 629.9 = 10.5$ the per cent yield of the highest yield attainable when no nitrogen has been added to the natural supply. Thus the soil under test is limited to a yield 10.5 per cent of the very highest yield attainable due to the limiting factor nitrogen. Now what does this imply in the soil? Let us see how we may arrive at the amount of available nitrogen present in terms of ammonium sulphate.

$$b = \frac{\log A - \log (A - y^0)}{c}$$

will give us the amount of available nitrogen (b) present in terms of ammonium sulphate: substituting

$$b = \frac{2.7993 - 2.7510}{.025}$$ or 1.93 dz/ha

Thus the amount of sulphate of ammonia in one hectare of surface soil to a depth of 14 cm. is in this instance but 1.93 double zentner, and is responsible for a 10.5 per cent "A" yield. This step completes the analysis of the particular soil as regards available nitrogen in terms of ammonium sulphate, the calculation may then be carried further and results secured as the element nitrogen.

Potash and phosphoric acid, the other two fertilizer constituents, may be arrived at without converting the pot yields to field basis at the outset. There has been added to the pots sufficient of each of these ingredients to result in the "Höchstertrag A". Thus $(90.7 \times 100) \div 113 = 80.3$, the per cent yield of the highest yield attainable with no additional potash. This is equivalent to 1.86 dz/ha of a potash salt containing 40 per cent K_2O, the action factor or (Wirkungswert), of which is .38 in the presence of sodium. The figure of 1.86 dz/ha is arrived at through substitution in formula:

$$b = \frac{\log A - \log (A - y^0)}{c}$$

There being but 1/6 soil in each pot and 5/6 sand, correction must be made for same. The sand previously determined contains available potash to the extent of .44 dz/ha, deducting this from 1.86 leaves but 1.42 dz/ha of a 40 per cent K_2O potash salt in 1/6 of the quantity of surface soil, therefore, 1.42×6 or 8.52 double zentner is the quantity of a 40 per cent potash salt present in 1 hectare of surface soil 14 cm. in thickness.

The available phosphoric acid content of the soil is arrived at in the same manner—thus $(66 \times 100) \div 113 = 58.4$, the per cent yield of the highest yield attainable. Substituting and solving for (b) we find that the soil contains 3.81 dz/ha of phosphoric acid expressed as Thomas slag having an action value (Wirkungswert) of 0.1. Correcting for the phosphoric acid found in the 5 kg.

of sand equivalent in terms of Thomas slag to 1.00 dz/ha, leaves 2.81 dz/ha remaining in the 1/6 soil portion, multiplying by 6 results in 16.86 dz., which is the quantity of Thomas slag of 16.3 per cent P_2O_5 content present in 1 hectare of surface soil 14 cm. in thickness.

We have now the desired information, viz., the quantities of the three chief plant food elements present in the soil and available to the plant in terms of fertilizer constituents. The plant has indicated quantitatively by its response the available plant food in the particular soil under investigation. It is unnecessary to follow the process for a determination of (b) through formula, for Mitscherlich has computed all these values and arranged them in tabular form. Thus all that is required in the way of calculation is the determination of the per cent yield of the highest yield attainable. Given this figure, which in the case of nitrogen in this example, proves to be 10.5 per cent, we locate same in the column headed Sulphate of Ammonia and by interpolating, find under heading "Present in Soil dz/ha" the amount of the fertilizer constituent as between 1.9 and 2.0 dz/ha, as near as possible to the figure arrived at through calculation, viz., 1.93.

TABLE I

Table of Yield for the Chief Plant Food Constituents and for a Typical Fertilizer Material of Each

	Yields Per Cent of Highest Yields Attainable						
Present in Soil dz/ha	Potash K_2O In Presence of Sodium	40 Per Cent Potash Salt In Presence of Sodium	Potash K_2O Without Sodium	Phosphoric Acid P_2O_5	Thomas Slag 16.3 Per Cent P_2O_5	Nitrogen (N)	Sulphate Ammonia 20.5 Per Cent N
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	19.3	8.4	7.3	12.9	2.3	2.8	0.6
0.2	34.8	16.0	14.1	24.1	4.5	5.5	1.1
0.3	47.4	23.1	20.4	33.9	6.7	8.1	1.7
0.4	57.5	29.5	26.2	42.5	8.8	10.6	2.3
0.5	65.7	35.4	31.6	49.9	10.9	13.1	2.8
0.6	72.3	40.8	36.6	56.3	12.9	15.5	3.4
0.7	77.7	45.8	41.2	62.0	14.9	17.8	3.9
0.8	82.0	50.3	45.4	66.9	16.8	20.1	4.5
0.9	85.4	54.5	49.5	71.2	18.7	22.3	5.0
1.0	88.2	58.3	53.2	74.9	20.6	24.5	5.6
1.1	90.5	61.8	56.6	78.1	22.4	26.6	6.1
1.2	92.3	65.0	58.8	80.9	24.1	28.6	6.7
1.3	93.8	68.0	62.8	83.4	25.9	30.6	7.2
1.4	95.0	70.6	65.5	85.5	27.6	32.5	7.7
1.5	96.0	73.1	68.0	87.4	29.2	34.4	8.3
1.6	96.7	75.3	70.3	89.0	30.8	36.2	8.8
1.7	97.4	77.4	72.5	90.4	32.4	38.0	9.3
1.8	97.9	79.3	74.5	91.7	33.9	39.7	9.8
1.9	98.3	81.0	76.4	92.8	35.4	41.4	10.4
2.0	98.6	82.6	78.1	93.7	36.9	43.0	10.9
2.1	98.9	84.1	79.7	94.5	38.3	44.6	11.4
2.2	99.1	85.4	81.2	95.2	39.7	46.1	11.9
2.3	99.3	86.6	82.6	95.8	41.1	47.6	12.4
2.4	99.4	87.7	83.9	96.4	42.5	49.0	12.9
2.5	99.5	88.8	85.0	96.8	43.8	50.4	13.4

Present in Soil dz/ha	Potash K_2O In Presence	40 Per Cent Potash Salt of Sodium	Potash K_2O Without Sodium	Phosphoric Acid P_2O_5	Thomas Slag 16.3 Per Cent P_2O_5	Nitrogen (N)	Sulphate Ammonia 20.5 Per Cent N
2.6	99.6	89.8	86.1	97.2	45.0	51.8	13.9
2.7	99.7	90.6	87.1	97.6	46.3	53.2	14.4
2.8	99.8	91.4	88.1	97.9	47.5	54.5	14.9
2.9	99.8	92.1	89.0	98.2	48.7	55.7	15.4
3.0	99.8	92.8	89.8	98.4	49.9	56.9	15.9
3.2	99.9	93.9	91.4	98.8	52.1	59.3	16.8
3.4	99.9	94.9	92.6	99.1	54.3	61.5	17.8
3.6	100.0	95.7	93.7	99.3	56.3	63.6	18.7
3.8	100.0	96.4	94.6	99.5	58.3	65.6	19.6
4.0	100.0	97.0	95.3	99.6	60.2	67.5	20.6
4.2	100.0	97.5	96.0	99.7	62.0	69.3	21.5
4.4	100.0	97.9	96.5	99.8	63.7	70.9	22.4
4.6	100.0	98.2	97.0	99.8	65.3	72.5	23.3
4.8	100.0	98.5	97.5	99.9	66.9	74.0	24.1
5.0	100.0	98.7	97.8	99.9	68.4	75.4	25.0
5.5	100.0	99.2	98.5	99.9	71.8	78.7	27.2
6.0	100.0	99.5	99.0	100.0	74.9	81.5	29.2
6.5	100.0	99.7	99.3	100.0	77.6	83.9	31.2
7.0	100.0	99.8	99.5	100.0	80.0	86.0	33.2
7.5	100.0	99.8	99.6	100.0	82.2	87.8	35.1
8.0	100.0	99.9	99.7	100.0	84.1	89.4	36.9
8.5	100.0	99.9	99.8	100.0	85.5	90.8	38.7
9.0	100.0	100.0	99.9	100.0	87.5	92.0	40.4
9.5	100.0	100.0	100.0	100.0	88.8	93.1	42.1
10.0					90.0	94.0	43.8
10.5					91.1	94.8	45.4
11.0					92.1	95.4	46.9
11.5					92.9	96.0	48.4
12.0					93.7	96.6	49.9
12.5					94.4	97.0	51.3
13.0					95.0	97.4	52.7
13.5					95.5	97.7	54.0
14.0					96.0	98.0	55.3
14.5					96.4	98.3	56.6
15.0					96.8	98.5	57.8
16.0					97.5	98.9	60.2
17.0					98.0	99.2	62.4
18.0					98.4	99.4	64.5
19.0					98.7	99.5	66.5
20.0					99.0	99.6	68.4
21.0					99.2	99.7	70.2
22.0					99.4	99.8	71.8
23.0					99.5	99.8	73.4
24.0					99.6	99.9	74.9
25.0					99.7	99.9	76.3
26.0					99.7	99.9	77.6
28.0					99.8	100.0	80.1
30.0					99.9	100.0	82.2
35.0					100.0	100.0	86.7
50.0					100.0	100.0	94.4
75.0					100.0	100.0	98.7
100.0					100.0	100.0	100.0

Interpretation of Results and Applicattion of Same to Practice

Following through with the example as carried forward. In the surface stratum of soil, 1 hectare in area of a 14 cm. thickness there is available nitrogen equivalent to 1.93 dz/ha of sulphate of ammonia, available potash equivalent to 8.52 dz/ha of a 40 per cent potash salt and available phosphoric acid equivalent to 16.86 dz/ha of a 16.3 per cent Thomas slag. Since the root mass of most all field crop plants is not confined to the shallow surface layer represented by the 14 cm. thickness, but occupies the substratum as well, Mitscherlich dealing as he does with general field crops makes provision by multiplying the above quantities each by 2. This provides for a soil layer 28 cm. or 11 inches and fairly well covers the feeding zone of most farm crops. Mitscherlich admits that this arbitrary manner of providing for subsoil plant food content is the weakest point in the whole procedure, but feels justified in taking this course since the method provides for a very accurate determination of the actual available plant nutrients in a definite layer of certain thickness, which is decidedly more exact and to the point than may be revealed by a chemical analysis of 100 grams of the soil. For more details on defense of his manner of dealing with results, see *Die Bestimmung des Düngerbedürfnisses des Bodens,* pages 57 to 60 inclusive. With the plant food in the soil stratum occupied by the root mass now double, we find on consulting Table I that the per cent yield of the highest yield attainable (A), for each fertilizer constituent has likewise changed. Thus with a sulphate of ammonia content of 2 × 1.93 or 3.86 dz/ha present in soil, we find that a 20 per cent yield is the highest possible; 2 × 8.52 = 17.04 dz/ha potash salt resulting in a yield (A). Since all that is required is 7.5 dz/ha of a 40 per cent potash salt, there is left in reserve a balance of 9.5 dz/ha. As to phosphoric acid, 2 × 16.86 = 33.72 dz/ha Thomas slag resulting in yield (A), see Table I, leaving 3.7 dz/ha in reserve. The soil is particularly deficient in nitrogen and although there is more than sufficient potash and phosphoric acid for a 100 per cent "A" yield, yet a 20 per cent crop only may be grown unless the nitrogen content is raised.

The discussion has been limited to the indicator crop oats. The next step is to apply the findings to any cultivated crop which has its feeding area within the zone designated, viz., a soil stratum 28 cm. in thickness. Below find in Tables II and III, application of the principles covering a rotation in general field crops:

TABLE II

Example of a 6-Year Crop Rotation

Crop		Yield dz/ha	Plant Foods in dz/ha Removed Nitrogen (N)	Potash K_2O	Phosphoric Acid P_2O_5
1 Potatoes.......	Tubers..................	200	0.64	1.20	0.28
	Tops....................	60	0.18	0.51	0.10
2 Rye...........	Grain....................	20	0.28	0.12	0.17
	Straw....................	50	0.23	0.50	0.13
3 Oats nurse crop for clover....	Grain....................	25	0.45	0.13	0.21
	Straw....................	50	0.33	0.80	0.18
4 Red Clover.....	Hay.....................	50	(0.99)	0.75	0.28
5 Rye...........	Grain....................	22	0.31	0.13	0.19
	Straw....................	55	0.25	0.55	0.14
6 Oats...........	Grain....................	25	0.45	0.13	0.21
	Straw....................	50	0.33	0.80	0.18
Totals removed......................			3.45	5.62	2.07
Returned to (1) 300 dz/ha and to (5) 150 dz/ha a total of 450 dz/ha of barnyard manure			0.90	2.00	0.00
Balance to be replaced by fertilizers.......			2.55	3.62	2.07

which implies in terms of ammonium sulphate 13 dz/ha; of a 40 per cent potash salt 9 dz/ha; and of a 16.3 per cent Thomas slag 12 dz/ha.

On computation and reference to Table I, it will be noted that nitrogen in some form must be added quite generously to bring up the yields of all crops that may be grown, assuming that the field on which the above rotation is to be followed has been found to contain the quantities of plant food indicated by our experimental oat crop grown in pots.

The potato crop may be heavily fertilized with nitrogen without danger, but cereals will allow of limited amounts only or lodging will follow, or possibly, even root damage. This does not permit of a building up of the nitrogen reserve quickly, and legumes should be seeded in the grain crops providing a green manuring which makes growth after the cereal crops have been harvested. This manner of management will add both nitrogen and organic matter and if to each cereal crop sufficient nitrogen from commercial fertilizers be added to provide for what is removed by the crop plus a small excess and to each root crop a generous supply, well exceeding the quantity removed, it will not be a difficult matter to maintain the fertility at a point so that a yield 50 per cent of the highest yield attainable may be expected, provided the potash and phosphoric acid contents are not allowed to fall below the amounts required to produce the "A" yield.

Suppose the aim is to maintain a 50 per cent "A" yield, for example a 50 per cent potato crop and a 50 per cent oat yield, etc., throughout this cycle, bearing in mind the important matter of excess nitrogen when dealing with cereals, yet leaving the soil at the end of the sixth year capable of producing, on reasonable fertilization, a 50 per cent "A" yield. By following the scheme as laid out in Table III, we should attain this objective.

TABLE III

Balance Sheet

Elements Found Present in Quantities Sufficient to Produce a 20 Per Cent "A" Yield at Beginning of Rotation Scheme, Table II

Nitrogen	.77 dz/ha
Potash	6.82 dz/ha
Phosphoric Acid	5.50 dz/ha

PLANT FOOD ELEMENTS IN DZ/HA

Crop	Added to Soil Nitrogen N	Potash K_2O	Phosphoric Acid P_2O_5	Removed by Crop Nitrogen N	Potash K_2O	Phosphoric Acid P_2O_5
1st year—Potatoes	1.20	1.33	none	.72	1.71	.38
2nd year—Rye and Green Manure	.92	none	none	.51	.62	.30
3rd year—Oats	.61	none	none	.88	.93	.39
4th year—Clover	.99	none	none	.99	.75	.28
5th year—Rye and Green Manure	1.00	none	none	.56	.68	.36
6th year—Oats	.64	.67	none	.78	.93	.39
Totals	4.37	2.00	0.0	3.45	5.62	2.10
Present at outset	.77	6.82	5.50	——	——	——
Total present and added	5.14	8.82	5.50			
Total removed	3.45	5.62	2.10			
Remaining at beginning of seventh year	1.69	3.20	3.40			
Required to produce 50 per cent "A" yield of potatoes	.78	none	none			

N added through manure .90 dz/ha, through commercial fertilizer legumes and green manure 3.47 dz/ha. Total N in terms of ammonium sulphate 21.85 dz/ha. K_2O added through manure 2.00 dz/ha in terms of a 40 per cent potash salt 5.0 dz/ha.

Note: Beginning with the seventh year although it may still be possible to secure the 50 per cent "A" yields without additional P_2O_5, it will be well to return to the soil henceforth both K_2O and P_2O_5 in quantities equal to what is annually removed by the crop.

For those who desire to learn more of the Mitscherlich method of pot testing and application of results, the writer desires to make known that there is now in process of preparation a translation of Marquart on *Mitscherlich's Instruction on the Determination of the Fertilizer Requirements of the Soil.* The writer has drawn heavily on the following in the preparation of this article:

Mitscherlich—1925 Die Bestimmung des Düngerbedürfnisses des Bodens.
—1925 Ein Leitfaden zur Anwendung der künstlichen Düngemittel.
Marquart—1925 Eilhardt Mitscherlich's Lehre von Bestimmung des Düngerbedürfnisses des Bodens.

To thoroughly understand Mitscherlich's manner of arriving at a solution of the problems of chemical soil analysis through plant physiology, one must study all of the articles he has published. Translations of the above mentioned pamphlets will greatly assist those interested.

Chemical Control in the Construction of Hydraulic Earth-fill Dams

By F. E. Hance

The following paper deals with a description of the chemical control now in vogue in the building of the Alexander Dam, McBryde Sugar Company, Ltd., Eleele, Kauai, under the supervision of Joel B. Cox, engineer in charge of construction.

The control is maintained by the department of chemistry of the Experiment Station, H. S. P. A., in Honolulu, the data being periodically forwarded to Mr. Cox for his use at the building site.

This paper also contains a discussion of the researches of the department of chemistry which led to an inspection of several outstanding mainland hydraulic fill dams under construction or completed.

A chemical development in soil treatment, which was later adopted at the building site, is discussed.

The reactions of a few nationally prominent engineers and chemists to the chemical soil treatment scheme are included in the discussion.

Descriptions and photographs are shown:

- (a) of two California dams during failure,
- (b) of the unusually successful venture of the Miami Conservancy District, and
- (c) of the construction operations at the building of the Saluda Dam in South Carolina (the largest hydraulic-fill dam in the world for power purposes).

At most elevated locations in the Islands the construction of a dam can be accomplished with the greatest economy by the hydraulic gravity sluicing of earth-fill material across a canyon stream bed.

At the site of the Alexander Dam the geological and topographical conditions of the locality favored the building of such a type of structure. Mainland undertakings of this character, after completion, have proven, in some cases to be sound earth structures, and in other cases have been entirely unsatisfactory.

An unusually successful and effective series of very large hydraulic-fill dams have been completed in the Miami Conservancy District in the vicinity of Dayton, Ohio. There are many other successful structures. On the other hand, two outstanding partial failures of this type of dam are those located at Lafayette and Calaveras in California.

In the construction control of the Alexander Dam, Mr. Cox took into consideration various engineering practices, developments and tests which had commonly or uncommonly been employed in other similar operations of this character. He found that a more exact and thorough knowledge would be required of the physical and chemical properties of the materials going into this dam if he were to maintain the project within the economic and safety limits as laid down in the specifications.

Aided by Messrs. Tester and Williams, Mr. Cox developed a scheme of soil testing which was later refined and expanded at the Experiment Station by bringing the various procedures within the control of fundamental laws in physical chemistry.

A system of engineering tests in soil mechanics had recently been described by Dr. Charles Terzaghi, of the Massachusetts Institute of Technology. By using original apparatus of special design, Dr. Terzaghi has shown that future predictions of consolidation and stability may be rather accurately made on fresh core materials intended for use in a hydraulic-fill structure.

Dr. Terzaghi's articles were published in the *Engineering News-Record* beginning November 5, 1925, and appeared weekly throughout the remainder of the year's publications.

Lacking laboratory facilities, equipment and operatives to investigate the Terzaghi developments for their possible control value at the site of the dam, Mr. Cox requested the Experiment Station to take up this work and combine it with the chemical researches which were already in progress at Honolulu. With G. R. Stewart's approval, the writer and C. W. Nesbitt, assistant chemist, thereafter cooperated with Mr. Cox in inaugurating a general scheme of chemical and engineering control, which was carried along and frequently modified during the building of the 50-foot pilot dam at the upstream toe of the proposed main structure. A study had been made in a classification of the soil materials which constituted the deposit (spoil bank) from which the fill for the dam was being sluiced.

A problem of selection in "beach" (coarse) and "core" (fine) materials was recognized at the outset. The spoil bank offered an almost unlimited supply of fill material, but it consisted of an heterogeneous agglomerate of widely variable physical characteristics. The colloidal character of this spoil bank soil was given a thorough study. A correlation between percentage of colloids, characteristics of "fines," settling out properties in aqueous suspension, soil reaction and other physical properties was gradually brought into a definite scheme of selective control. The coarse or "beach" material offered no problems of a chemical nature. The core which was being deposited in the pool of the dam constituted that portion of the structure which governed to a great extent the future stability of the entire project. Problems of settlement, consolidation, impermeability and rigidity were encountered which required a solution in terms of a future condition in the core after about 60 feet of new fill had been placed upon the then exposed elevation from which a sample had been withdrawn.

This requirement entailed the development of a means of securing data by chemical and engineering methods which amounted essentially to a schedule of predictions in the constants required. The accuracy of these predictions was subjected to as many reliable tests as could be devised. The whole scheme of control was then modified as far as possible to meet the requirements of the engineer, with the fewest complications of cumbersome technic.

By the time the pilot dam had been completed a comprehensive procedure of tests and determinations had been placed on a practical basis.

The newly developed scheme of control contained many features which were new in engineering use. On each core sample coming to Honolulu we were able to return the following information and data:

1. Reaction on the pH scale (acid or alkaline).

2. Settlement characteristics from a suspension in water and percentage of colloidal matter at different stages in the settlement.
3. Effect on true colloidal dispersion by neutralization of natural acidity with alkali and subsequent behavior when made quite alkaline.
4. Solubility characteristics of the material and its resistance to chemical change when in long contact with impounded water.
5. True specific gravity—a very valuable guide in detecting a material of poor packing qualities.
6. A minimum percentage of water content which will admit of:
   (a) a degree of plasticity compared to a standard (adhesive properties).
   (b) a degree of granulation at a point where the mass refuses to adhere when rolled out to a thin cylinder (brittleness).
   (c) a degree of "drying out" at a point where the mass cracks and fissures (cracking point).
7. A ratio of void spaces to solid material as the core is subjected to the load above it during construction.
8. The compression properties or elasticity of the core under increasing and decreasing loading.
9. The consolidation to expect of the material after it has been loaded with 60 feet (more or less) of additional core. (This range has recently been extended to 100 feet.)
10. The resistance to a movement of water under the conditions of 9 when subjected to a measured hydrostatic head of impounded water. This determination is made as a test of "permeability" and is separately determined for various increments of loading.
11. The microscopic examination of the material for shape of grain and colloidal dispersion and recorded for reference and description by micro-photographic methods.
12. Calculations and mechanical curve plotting of the mathematical data produced in the various tests.

All the above tests are separately made on the spoil bank deposits—the original material for sluicing into the core.

When applied to core material freshly laid down, the whole series of tests enables the engineer to secure an estimation of how that material is going to, or at least should, behave after it has gotten beyond his reach and has become a part of the dam. The rapidity of construction and factors of safety in the structure are thus made dependent, to a marked degree, on the results of the program of control.

During the course of the experiment work on the Alexander Dam cores at the department of chemistry in Honolulu, it was found that a treatment of the soil material with common alkali gave it the exceptional properties of high impermeability and apparently a plastic, clay-like consistency. Further researches on this treatment of the core soil gave indications that the idea might be used to practical advantage in preparing the fill for the core wall under the foundations of the main dam.

In excavating the core trench to bedrock for the core wall foundation, Mr. Cox

found that a layer of gravel several feet thick was situated below and was spread out parallel with the valley floor. The possibility existed that excessive seepage might eventually find its way through this gravel after the dam had been completed above it. It was recognized that a rapid movement of waters beneath the foundation of the dam would constitute a potential menace of undermining the entire structure. A manner of blocking this possible flow was proposed in surrounding the concrete core wall with the alkaline-treated core soil which had proved so dense and impermeable in the laboratory experiments. The plan involved the laying down of two longitudinal blankets of chemically treated soil across the core trench and on either side of the concrete cut-off wall. This operation would break the continuity of the under stratum of gravel and place in the flow path a V-shaped deposit of very impermeable fill, supported by the core wall in the center and trench cut on the sides. Consolidation properties of the alkaline-treated soil were found to be satisfactory and the permanence of the treatment itself was established as a dispersed condition of long duration with little likelihood of drastic change in this condition after consolidation.

A point had been reached in the building operations where sluicing had been stopped on the pilot dam preparatory to advancing with the main structure. The core trench was being excavated to bedrock.

Many features of the developed control program and the proposed chemical treatment of fill in core trench were not as yet described in the literature or in use at other projects, nor were they matters ever having been given engineering precedence or trial, as far as we could determine. It was proposed, therefore, that the plans be submitted to noted individual mainland authorities of national reputation and experience.

The development of the alkaline core treatment scheme to a point of possible utilization in dam construction was largely due to Mr. Stewart's encouragement in bringing the researches to a definite conclusion. He gave the investigation considerable of his personal attention and at the conclusion of the work he urged that the scheme be given every possible authoritative criticism before advising that it be adopted in the building program.

On March 18, 1929, the writer was authorized to visit such mainland individuals, institutions and construction operations as would insure a thorough and comparable investigation of similar continental projects. Criticism of our control program and proposed scheme of chemical soil treatment was also to be sought.

We carried the soil treatment scheme to the mainland authorities with Mr. Stewart's and the writer's firm belief in its usefulness but with open minds on its practical utilization. The trip was made and investigation completed between March 28 and June 11, 1929.

The report on the above trip is as follows:

Dr. Nathan A. Bowers (Ph.D. in Engineering):

Dr. Bowers is the Pacific Coast editor of the *Engineering News-Record,* with offices at the McGraw-Hill Building, 883 ~~Mission~~ St., San Francisco, California. Dr. Bowers had previously been advised by letter as to the objectives of the trip. In the first conference at San Francisco he offered his office as headquarters and urged that full use be made of his library and office force. He discussed the

Alexander Dam testing program and also the proposed alkaline core-fill scheme for use around the cut-off wall. He was enthusiastic in his endorsement of both schemes and stated that many features of the testing program and the proposal for chemical soil treatment were new to the engineering profession. He requested that we contribute a series of papers to the *Engineering News-Record* which would carry a description of the researches which led to the development of the control program and to the chemical soil treatment.

Dr. Bowers later made arrangements for the inspection of the Lafayette and Calaveras Dams, the San Leandro, San Pablo and Hetch Hetchy projects. He made introductions in person and by letter to various West Coast water project officials with whom the problems of the Alexander Dam were discussed.

Dr. Bowers was frequently consulted during the course of the investigation. His advice, assistance and influence were invaluable aids in realizing the objectives of the trip. The mainland itinerary was revised in his office. Many future appointments and introductions were very kindly arranged by letter from his office.

Mr. George W. Hawley, chief engineer, East Bay Water Company, Oakland, California:

Mr. Hawley has built several hydraulic-fill dams in northern California. He approved of the inspection of the Upper and Lower San Leandro projects as advised by Dr. Bowers, and also of the San Pablo Dam (all built by Mr. Hawley). He examined the control data and the proposed chemical soil treatment at the Alexander Dam. He related his experiences with hydraulic type of structure and pointed out details in construction in which he advised the exercise of the greatest of caution. The slope of the dam and design of spillway were, in his estimation, of vital importance. His suggestions on these constructional details were noted and sent to Mr. Cox. Owing to Mr. Hawley's wide building experience, information and criticism were particularly requested as to the design and height of the cut-off wall and propsed chemical soil treatment in cut-off trench at the Alexander Dam.

During the course of his reply he stated: "If cut-off wall serves only as a baffle its height is of importance in creating a longer path of underground seepage. If, on the other hand, you intend to surround the wall with the highly impermeable and chemically treated soil, a shorter height will suffice."

Mr. Hawley approved of the scheme of surrounding the core wall with the alkaline-treated soil fill. He asked, however, what proof we had that a reversible reaction would not eventually cause the treated soil to revert to its original condition. In reply the colloid dispersion phenomenon was explained in some detail, showing the almost complete disintegration of granular soil to an impalpable fineness by the treatment, and of the difficulty, after consolidation, of any water or solution reaching beyond the inner surfaces of the soil in mass. This point had been previously settled by experiment in Honolulu. Mr. Hawley's interest in the Alexander Dam may be shown by the fact that he requested two days' examination of plans and data before the discussion of the project.

Mr. Hawley very kindly also offered to conduct the writer's inspection of the San Pablo structure in person.

Dr. Charles Terzaghi, Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology, Boston, Mass.:

A large proportion of the control measures being employed at the Alexander Dam were derived from Dr. Terzaghi's published articles and from Professor Andrews' (University of Hawaii) lecture notes on Terzaghi concepts. Professor Andrews also very kindly assisted us in inaugurating the Terzaghi tests and loaned us his apparatus for the work.

All the data of the control measures, proposed chemical treatment of core wall fill and construction plans of the Alexander Dam were submitted to Dr. Terzaghi in Boston.

Four days were spent with him in his laboratories. He discussed at length the application of control measures for hydraulic-fill dams and also took up the subject of the alkaline core fill in the cut-off trench at the Alexander Dam. He expressed unqualified approval of the chemical soil treatment for the purposes which were described. He pronounced the scheme as unique and showed by explanatory sketches and mathematical calculations how the treatment would be of value when confined in the core trench, but of little value in the main dam without unusually heavy beach superstructures.

(The proposed treatment included only the V-shaped wedge on either side of the core wall below the valley floor.) Dr. Terzaghi's aides, Dr. Glennon Gilboy and A. Casagrande, gave us very valuable information and instruction in operating the Terzaghi apparatus and in conducting the tests. This information was of the greatest importance because of the fact that it is still unpublished and is not obtainable from any other source.

As a result of the experiences with these gentlemen in Boston, our program of testing in Honolulu has been given the benefit of their many years of research in the applications of Terzaghi's theories. We have since endeavored to bring our technic to a point comparable with the advised refinement given us by Dr. Terzaghi, Dr. Gilboy and Mr. Casagrande.

The interest shown in our core problems by these gentlemen prompted them to request that we forward them several samples from the Alexander Dam for a check on our results and a study of the effect of the proposed chemical treatment. Mr. Casagrande will make these studies in Vienna, Austria. This move is necessitated by the laws prohibiting the importation of Hawaiian soil to the mainland of the United States. We have forwarded the requested soil samples to Austria via Canadian routing.

Dr. Terzaghi has tentatively accepted an invitation to inspect the Alexander Dam in August, 1929. He will probably stop off in Honolulu on an already arranged trip to Japan.

During the stay in Dr. Terzaghi's laboratories, opportunity was found to note in writing many of the recommendations and suggestions which he advised for the testing program and for procedure at the dam. These notes have been passed on to Mr. Cox.

It appeared important to obtain the opinion of a group of experts in chemistry on a soil treatment which now had the endorsement of several prominent engineers. If used at Kauai, the scheme would involve the handling of about 2,000 tons of core soil and the purchase of about 50,000 pounds of soda ash.

The decision was reached to submit the scheme to the staffs of the department of chemistry and of the department of agriculture at Cornell University after the conclusion of the interviews with Dr. Terzaghi. Accordingly, a stop-over at Ithaca was made in moving southward from Boston.

Professor L. M. Dennis and Staff, Department of Chemistry, Cornell University, Ithaca, New York:

The relationships of physical and inorganic chemistry to the control program and to the alkaline soil treatment were looked into by these gentlemen. Professor Dennis expressed an agreeable surprise to find a chemical control and soil treatment so closely associated and so interrelated with an engineer's mathematical soil testing scheme. Professor Dennis and other staff members stated that the chemical measures of the testing and soil treatment in Honolulu were sound as far as they could judge by the description given and data submitted. The alkaline soil treatment scheme met with enthusiastic comment. The departure from the conventional in this respect was discussed but no objection was offered as to the soundness of the theories involved.

Professor T. L. Lyon and Staff, Agricultural College, Cornell University, Ithaca, New York:

These gentlemen discussed the proposed alkaline soil treatment from the agricultural chemist's viewpoint. Dr. B. D. Wilson suggested that the scheme, in his opinion, was entirely practical and would produce a dispersion in the soil colloids which would remain "put" indefinitely under the conditions of its use.

With the accumulated information and advice at hand from different sources and all endorsing the chemical soil treatment, it was deemed advisable to suggest to the engineer at the Alexander Dam to proceed with the treatment. Alexander and Baldwin, Ltd., agents for McBryde Sugar Company, Ltd., were advised by wire and Mr. Stewart, head chemist, Experiment Station, H. S. P. A., by letter, of the expert advices which had been received. Mr. Stewart, having previously considered the advisability of placing the treatment in the dam, reported further to the builders, suggesting the details and manner best suited for its utilization.

Mr. Nesbitt, assistant chemist, later cooperated with the McBryde Sugar Company, Ltd., in placing the treatment in the core trench.

Mr. F. E. Schmitt, editor, Engineering News-Record, McGraw-Hill Publishing Company, 10th Avenue at 36th Street, New York City.

Dr. Bowers had advised Mr. Schmitt that a call would be made on him in New York. The details of the soil treatment scheme and testing program were discussed with Mr. Schmitt and other staff members of the McGraw-Hill organization.

The alkaline soil treatment idea appealed to Mr. Schmitt as a very worthwhile undertaking. He showed keen interest in the chemical control and soil testing program. He complimented Mr. Cox on the originality of many of the control measures and expressed regret that similar studies were not in vogue in New York City on the soil foundation problems then giving trouble in upper Manhattan Island. Mr. Schmitt particularly requested that we submit a paper (or papers) which would carry descriptive matter of the theoretical and practical application of

chemical soil problems to foundation structures. He stated that this type of investigation has never been made for the use of the engineer. He stated that the problems in soil chemistry as applied to soil mechanics is an untouched field. He then cited instances in New York where an understanding of soil chemistry would undoubtedly have contributed to the solution of many troublesome foundation problems. Timely suggestions on asphalt reservoir lining and introductions to Eastern officials were secured at the McGraw-Hill office.

Mr. Schmitt and Mr. Richardson also very kindly arranged details of transportation, introductions, etc., for the inspection of the Saluda Dam in South Carolina.

The Saluda River Project—Columbia, South Carolina:

This is the largest hydraulic-fill dam in the world designed for power purposes, Murray and Flood, engineers, builders; A. R. Wellwood, resident engineer; J. G. Wardlaw, Jr., testing and control; Hamby, Darlington and Duncan, engineers.

The Saluda River Dam is at present under construction, in charge of Mr. Wellwood. The problems of hydraulic fill are here seen on an enormous scale. The crest of the dam when completed will extend somewhat over 1 1/3 miles in total length and the basin will cover seventy-eight square miles. The manner of sluicing the core material into place differs from the gravity flow scheme in use at the Alexander Dam. The upper and lower toes of the dam are simultaneously being constructed as dykes from which material for the core pool between is sluiced by a giant (water) discharge.

Seventeen trains on a standard gauge track are continuously hauling and dumping the soil fill from several "borrow pits" to the two parallel dykes. The water giants are operated from floating pumping stations. Pontoons in the central core pool carry a frame rigging, the latter supporting electric power cables used to convey electric current to the pumps which drive the giant discharge mechanism. As construction advances the rising pool floats all the units used for sluicing down the dykes.

The Saluda River, a large stream, has been diverted through arched conduits under the floor of the dam. These conduits will later serve as outlets in operating the hydro-electric generators.

Five concrete towers have been constructed to house the machinery for the operation of the gates at the entrance to the outlet tunnels. Mr. Wellwood has described the project very completely in *Engineering News-Record,* Vol. 102, No. 17, April 25, 1929, pp. 669-672.

Our chief interest in this project was one of comparison of materials and manner of construction with the Alexander Dam.

Mr. Wellwood very kindly extended every possible courtesy and aid for a very thorough inspection of the undertaking. Messrs. Hamby, Darlington and Duncan separately conducted tours of inspection in which different phases of the project were explained.

Mr. Wardlaw gave us a detailed account of the testing and control program at Saluda and made provision for obtaining samples of materials for comparison with Alexander cores.

The comparison investigation is in progress at this writing (July 5, 1929).

We are also exchanging ideas on methods of control and testing. We are expecting to find information of value to both projects after the comparison data have been compiled and studied.

Information of added value will no doubt be developed when these projects are compared with the testing data from Miami Conservancy, Lafayette and Calaveras Dams.

Unfortunately for us, Mr. Wellwood was very busy with conferences and executive detail during the brief stay in Columbia. Consultation was only possible on a few occasions of short duration. He expressed regret that he could not, at that time, go into a full discussion of our proposed soil treatment and testing program. We are, at present, corresponding with Mr. Wellwood and with Mr. Wardlaw on these matters.

A few photographs are shown which Mr. Wellwood permitted us to take and to use for illustrative purposes in this report.

The Miami Conservancy District, Dayton, Ohio:

This district is a political subdivision of the state of Ohio established in 1915 and exists for the purpose of building and maintaining flood control works in the Miami Valley. The history of the valley is replete with accounts of serious floods. In March, 1913, the Miami Valley was swept by a tremendous storm. The streams of the valley, fed by the steady downpour, rapidly rose and overtopped the levees. For three days the waters raced through the streets of Dayton, reaching a depth of twelve feet in Main Street at the peak of the flood. Thousands of people were marooned in attics and on roofs of houses, 400 lives were lost, 100 million dollars of property was destroyed, and the communities of the valley were rendered prostrate.

As a result of this calamity, the Conservancy District was established. The official plan provided for five basins formed by building hydraulic earth-fill dams across the streambeds which carried the flood waters. Substantial concrete outlets, founded on rock and passing through the base of each dam, permit the ordinary river flow to pass unobstructed. The sizes of the outlets are such that at times of highest floods, only such amounts of water will escape through them as can be safely taken care of in the river channels below the dams. The excess water is held back by the dams and accumulates temporarily in the valley lands situated above them, to flow off later through the outlets as the floods subside. Storage is designed for a total of 847,000 acre feet of water under maximum flooding conditions. Spillways are provided at all of the structures in order to keep the water level from reaching the crest of the dams, should such a flood come.

Inspections of these projects were made possible through the courtesy, cooperation and assistance of C. S. Bennett, in charge of the district, and of C. A. Bock, vice president, Morgan Engineering Company, the builders.

The materials which were used in the cores of the dams were examined and sampled at the borrow pits. Attention was given to the details of spillways and the outlets. All the dams appeared to be massive and secure. Ample evidence was given by the layers of debris within the basins to show that the dams had frequently functioned as the builders had planned. In no case had the impounded water ever risen to the elevation which would carry it over the spillway. The entire project has proven safe and secure. Since its completion the cities in the

Miami Valley have not only been free from any flood menace, but are guaranteed immunity in the future. Mr. Bennett stated that the spillways would not automatically operate until a flood came which would be 40 per cent greater in intensity than the 1913 disaster.

The materials from the Germantown structure are to be compared in a full testing program with the Alexander Dam and with the other mainland projects visited.

Both Mr. Bennett and Mr. Bock discussed the constructional features of the Alexander Dam with the writer. They very kindly made recommendations and offered valuable advices which we have passed on to Mr. Cox on Kauai.

Mr. Bennett issued a pass which gave the writer admission to all five projects, with permission to sample and photograph at will. Mr. Bock generously gave up half of his Sunday holiday, driving the writer to the three largest dams and stopping in each case for an inspection and explanation of constructional details and operating features.

The photographs taken at the dams of the Miami Conservancy District are shown herewith:

The Lafayette Dam, Lafayette, California:

The following brief description of this dam and its partial failure during construction is made possible through the courtesy of F. W. Hanna, superintendent of the East Bay Municipal Utility District of Oakland, California.

Mr. Hanna very kindly presented the writer with his personal copy of the "Report by the Consulting Board on Partial Failure During Construction of the Lafayette Dam."

This report is a very complete and beautifully arranged thesis. It contains a description of the dam, an estimation and analysis of the causes leading to its partial failure, a series of photographs which amplify the text and a recommendation for the correction of the failure with a full complement of descriptive charts and prints.

The Lafayette dam is situated in Contra Costa County, California, about 9 miles northeast of the City Hall of Oakland.

The dam, an earth embankment, designed to be 140 feet high, 1,400 feet long, extends in a nearly east and west direction across a small creek valley tributary to the Lafayette branch of Walnut Creek. The dam is a unit of the Mokelumne Project of the East Bay Municipal Utility District, and was intended to provide storage for 3,460,000,000 gallons (10,590 acre feet) of water to be pumped into the reservoir from the main aqueduct which passes through the valley of the Lafayette Branch of Walnut Creek. Construction was begun in August, 1927, and on September 17, 1928, when the dam lacked only about 22 feet of its intended height, a crack parallel with the axis, and a rise in elevation of the ground surface, were observed at the downstream toe of the embankment. Additional cracks soon appeared and the embankment began to subside until, on September 28, all appreciable movement had ceased, after the central part of the dam had sunk a maximum of about 24 feet at the crest. . . . The foundation under that part of the dam where the failure occurred is an alluvial deposit composed very largely of clay, with a depth ranging from 50 to 90 feet above the Orinda formation. The upper 10 to 15 feet of this material was dry and firm, but the remainder was moist and more or less plastic.

. . . . the fact that the dam rests directly on the plastic alluvium which in the deepest part of the dam is 90 feet or more in thickness, is, from the point of view of the geologist, the critical factor in the failure of the structure.

Through the courtesy of George B. Sturgeon, engineer in charge at the site, the writer was given the privilege to inspect, photograph and sample the structure as it now stands. Mr. Sturgeon very kindly conducted the inspection trip and assisted in securing the exhibits which are to be used as illustrative material in the general mainland investigation.

After a discusison of the project with Mr. Sturgeon, notes were later made which appear below:

Lafayette—slip-on dam—apparently due to alluvial sub-foundation. Abutment sides gave good bond where bedrock came close to surface. Valley floor was poor in some places—bed rock occurring probably more than 90 feet below surface. The dam (roll fill) slumped at core and bulged out at both toes. No flow of water occurred. Construction was not complete nor had spillway been built at time of failure. Repairs have been decided on. See Mr. Hanna at Oakland office.

It should be made very clear that the "notes" above do not quote Mr. Sturgeon's remarks. They are simply notations on impressions which remained on the evening of the day spent with Mr. Sturgeon as his guest.

While the slight failure was not due to a liquid core nor to any other inherent defect in the materials of the dam, samples were secured of core and borrow pit deposits which we plan to study in comparison with the other mainland projects visited and with the Alexander Dam at Eleele, Kauai.

The photographs appear herewith. Most of these prints have been reproduced from original photographs by W. Twigg Smith, illustrator at this Experiment Station.

Many of the photographs were obtained from the report presented to the writer by Mr. Hanna.

The Calaveras Dam, near Sunol, California:

This dam has a very interesting history. As it now stands, it has a height of 220 feet above bedrock, and encloses a reservoir area having a capacity of almost 33 billion gallons of water. The project is a part of the system which supplies the city of San Francisco with water. The lower portion of the dam was built by the hydraulic-fill method. When nearing completion, a part of the main core broke through the beach and flowed upstream. The tower which carried the mechanism to operate the outlet gates was snapped off at the base, moved 360 feet, and thrown over. The downstream face of the dam, the berms and supporting fill practically remained intact. No serious property damage, other than the injury to the structure, was occasioned by the break. But little water stood in the reservoir at the time of the core flow and as a result no flood occurred and no lives were lost.

The dam has been repaired and the project has been completed, using the roll-fill method of laying down the remainder of the core, which is supported by loosely dumped rock to form the complete structure.

A new tower and outlet tunnel have been constructed, as well as a most effective and substantial concrete spillway. The structure now stands as one of the most massive, secure and beautifully ornamental sites on the West Coast.

Through the courtesy of George A. Elliott, vice-president and chief engineer of the Spring Valley Water Company, an inspection of the project was granted. Mr. Elliott also very kindly prepared and presented us with a series of photographs showing the details of the flowout, the repairing of the dam and the finally com-

pleted structure. Mr. Elliott also introduced the writer to A. W. Ebright, superintendent of the Calaveras District, and arranged with Mr. Ebright for an inspection of the project. Through Mr. Ebright's courtesy and assistance, a sample was secured of the orginal core which flowed out in the break. Other samples were collected which were removed from the borrow pits used for hydraulic fill and from the deposits later used for the roll fill. These materials will be studied in comparison with the other mainland projects visited and with the cores of the Alexander Dam on Kauai. Reproductions of the photographs presented to us by Mr. Elliott follow. The negatives from the original prints were prepared by Mr. Smith, as in the case of the Lafayette photographs.

The construction plans and control program of the Alexander Dam were discussed with Messrs. Elliott and Ebright. Mr. Cox has been advised on the reactions of these gentlemen to the project on Kauai.

Many other projects and water systems were visited. A study was made of the manner of dam construction and spillway design at:

The Municipal Project of the Wichita Falls (Texas) Water District.
The Upper and Lower San Leandro basins in Northern California.
The San Pablo District of California.
The Hetch-Hetchy District of California.
The Municipal Water Systems of Boston, New York City, Ithaca, Philadelphia, Baltimore, Washington, Cincinnati, New Orleans, San Francisco and Los Angeles.

The experiences gained at the above-mentioned projects were varied. An attempt was made to learn of the difficulties encountered during the construction of the various dams.

In the eastern districts of the mainland the relatively denser population necessitated the construction of water systems of gigantic capacity. Most of these projects were built with reinforced concrete. Smaller basins of the hydraulic or roll-fill type were numerous, but the soil conditions were so favorable and funds so freely available that serious problems of dam security were seldom encountered.

The problem of sewage disposal and water contamination are engaging the principal attention of the Eastern water engineers and city officials.

In many of the large cities the water supply is pumped from a near-by river, filtered, chlorinated, and turned into the mains—all in one continuous process.

A few cases of seepage problems were found in the East, many in the West. This matter will be discussed in the report on reservoir sealing and ditch lining. Wherever time permitted and the engineer was so inclined, an opinion was obtained on the construction and control problems of the Alexander Dam.

Many systems of riprapping, grouting and plugging of subterranean tubular vents in dams and reservoirs were inspected and discussed with some of the engineers visited.

The courteous attention and kindly interest shown the writer on this mission by every individual or institution official ~~visited~~, assisted greatly in obtaining the information and experiences which were sought.

A paper will appear later in which a comparison study of the materials of mainland and Hawaiian dams will be discussed.

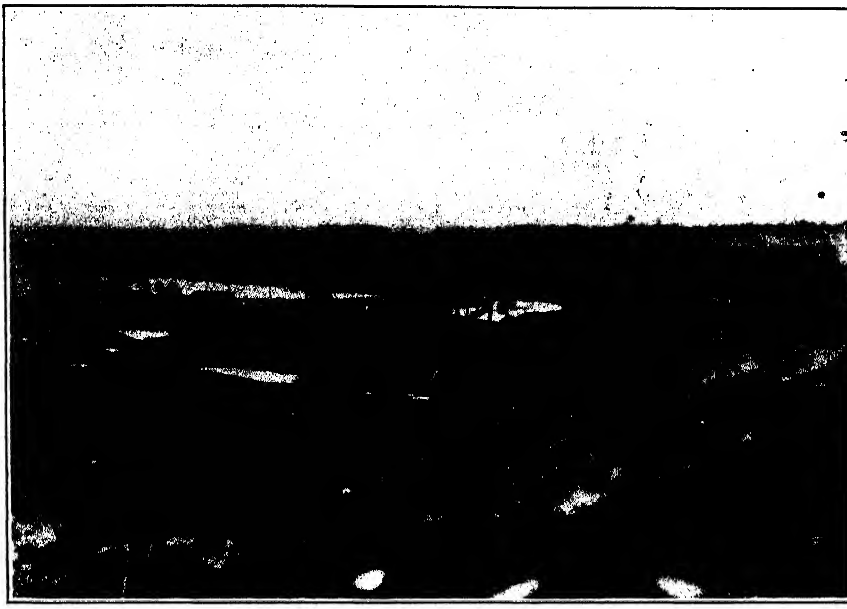


Fig. 1. Saluda Dam, Columbia, South Carolina.
Upper core pool area.
Saluda River in distance.
Two toes under construction.
May 1, 1929.

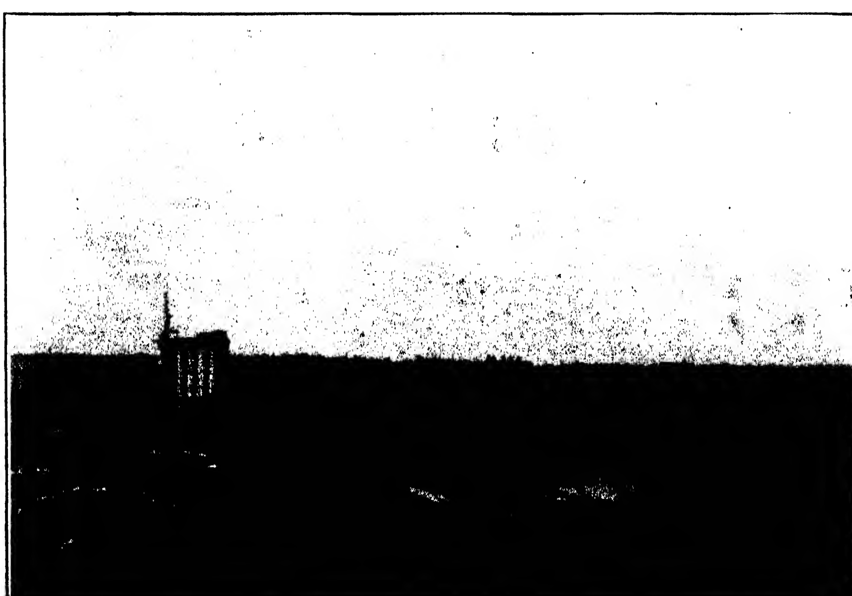


Fig. 2. Saluda Dam, Columbia, South Carolina.
Towers in background. One of the core pools in right foreground. Top of towers represent approximate height of dam when completed. Towers contain mechanism for operating outlet gates in control of the hydro-electric plant now under construction.
Saluda River is at present flowing under construction work in a series of tunnels at base of towers.
May 1, 1929.

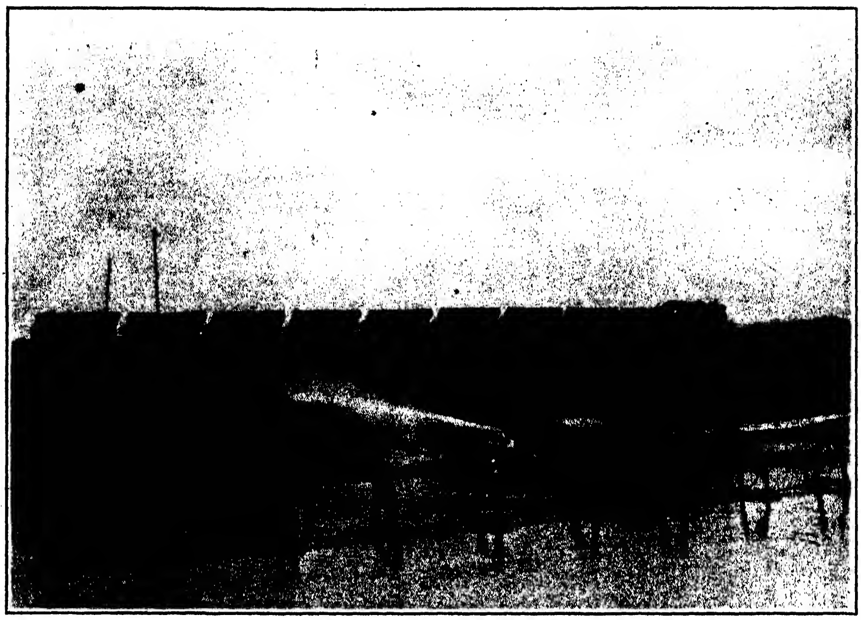


Fig. 3. Saluda Dam, Columbia, South Carolina.
Discharge of borrow-pit material. Giant in operation.
Pontoon floats in foreground. Source of pool is muddy water from Saluda River. Water in pool becomes clarified by contact with the borrow-pit fill. (Note clear water and white discharge from Giant). (The cause of this phenomenon is under investigation in this laboratory.)
May 1, 1929.

Fig. 4. Saluda Dam, Columbia, South Carolina.
Central core pool.
Upstream and downstream toes.
Floating pump houses.
Train carrying borrow-pit fill.
Pontoons supporting power cables to operate pumps for giants.
May 1, 1929.

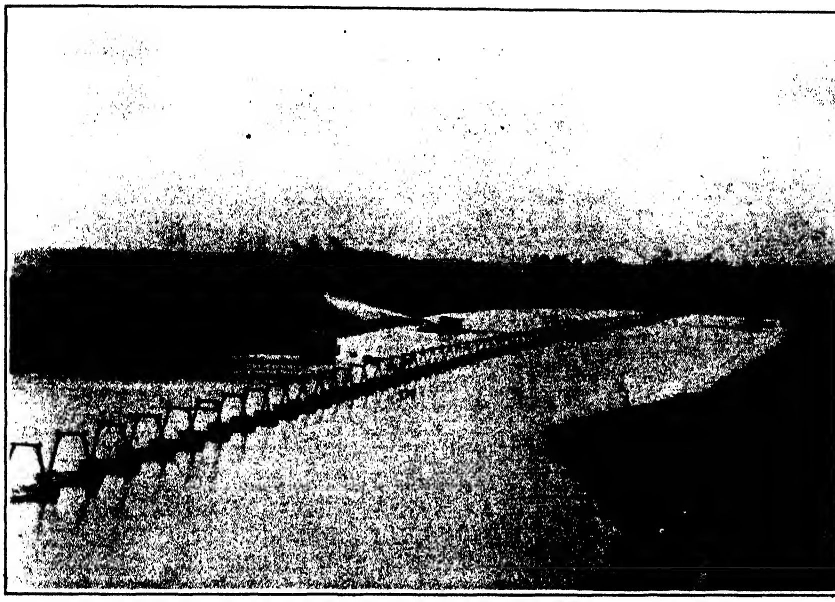


Fig. 5. Saluda Dam, Columbia, South Carolina.
Giants in operation.
Details of pontoons.
Showing both dykes and the core pool between toes.
May 1, 1929.

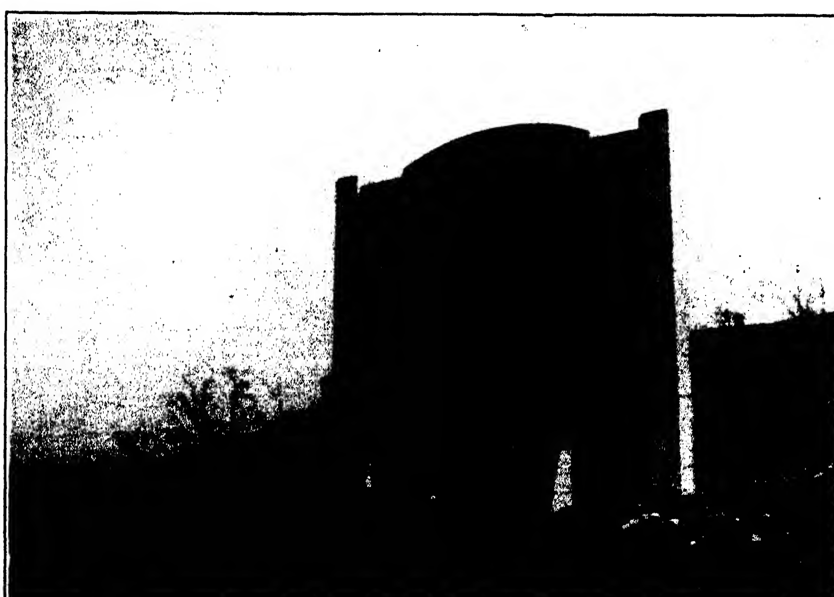


Fig. 6. Miami Conservancy Project.
Declaration of purpose.
May 4, 1929.

Fig. 7. Miami Conservancy Project—Germantown Dam.
Intake—diversion tunnel. Showing upstream face of dam and railing beside road across crest.
May 5, 1929.

Fig. 8. Miami Conservancy Project—Germantown Dam.
Outlet—diversion tunnel. Showing downstream face of dam and mechanical concrete device to reduce turbulence in stream discharge.
May 4, 1929.

Fig. 9. Miami Conservancy Project—Germantown Dam.
Spillway—constructed so as to operate automatically when peak flood waters reach volume 40 per cent greater than 1913 record.
May 5, 1929.

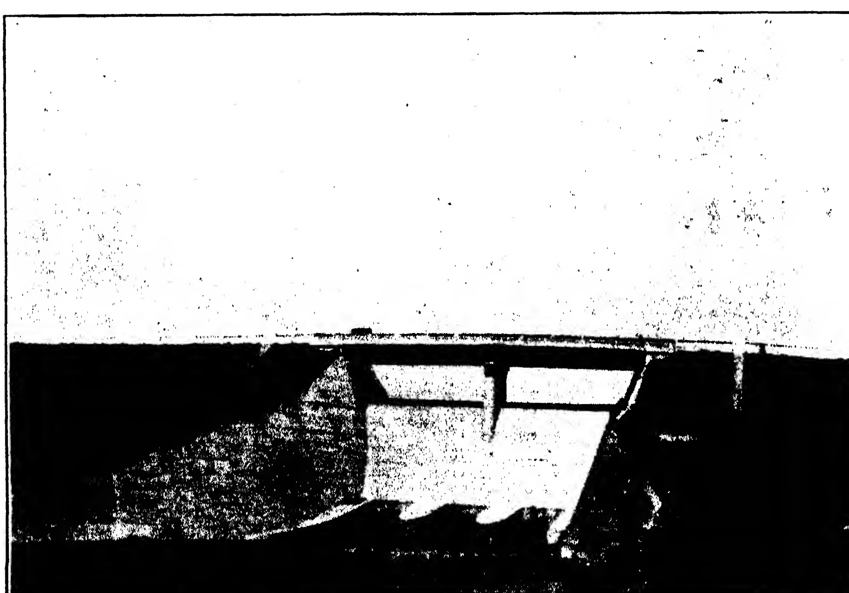


Fig. 10. Miami Conservancy Project—Huffman Dam.
Stream outlet, spillway, road and downstream face of dam.
May 5, 1929.

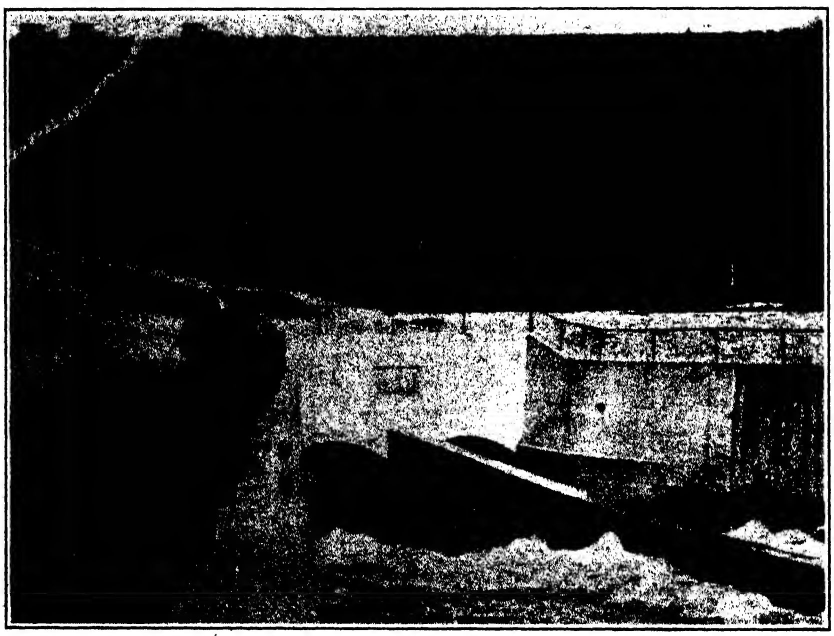


Fig. 11. Miami Conservancy Project—Englewood Dam.
Showing stream outlet, road on crest and downstream face of dam.
May 5, 1929.

Fig. 12. The Lafayette Dam—
Airplane view of the partial failure showing slump in the crest and bulge at both toes.

Fig. 13. Lafayette Dam, October 21, 1928.
Ridge pushed up at the downstream toe, seen from the east. At left may be seen a portion of the dam that has been thrust out over the original ground surface in the foreground.

Fig. 14. Lafayette Dam, October 21, 1928.
Subsidence along crest of dam as seen from the west. The principal limiting fissure which cuts a segment from the upstream slope appears on the right.

Fig. 15. Lafayette Dam, October 21, 1928.
View eastward along crest of dam, showing crescent-shaped zone of fissures. The surface of the down-dropped block north of the fissure zone is tilted downward in an upstream direction.

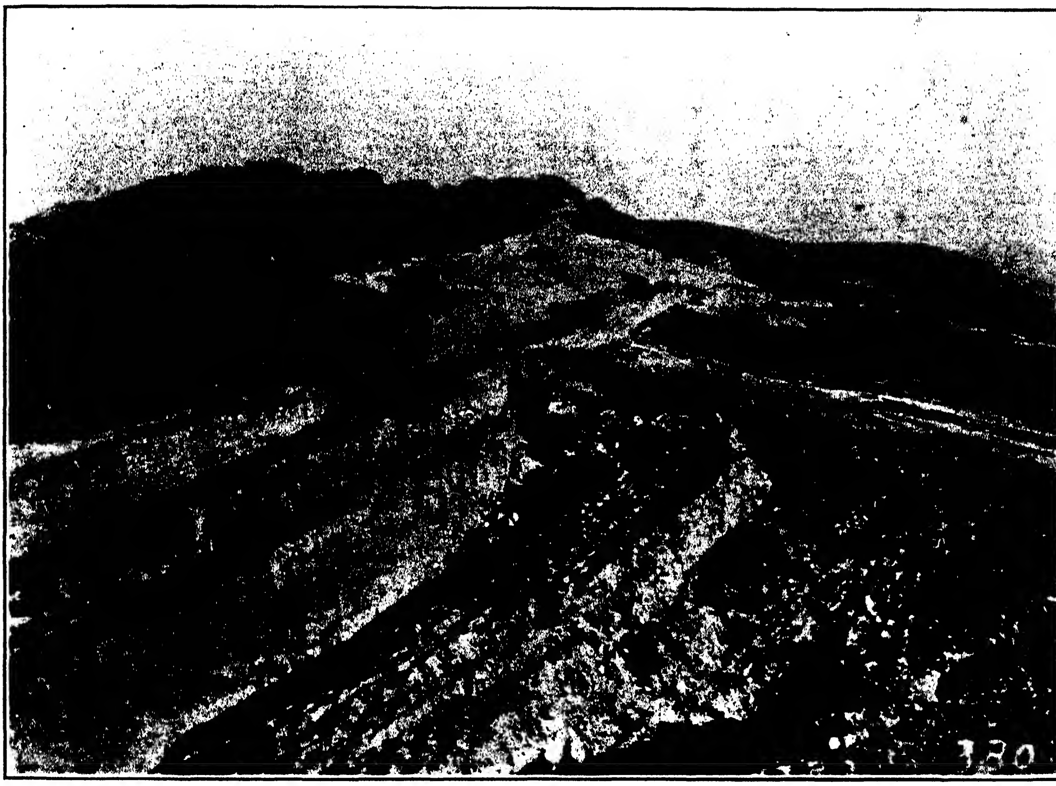


Fig. 16. Lafayette Dam, October 21, 1928.
Crevasses in upper part of the downstream slope of the dam, looking east.

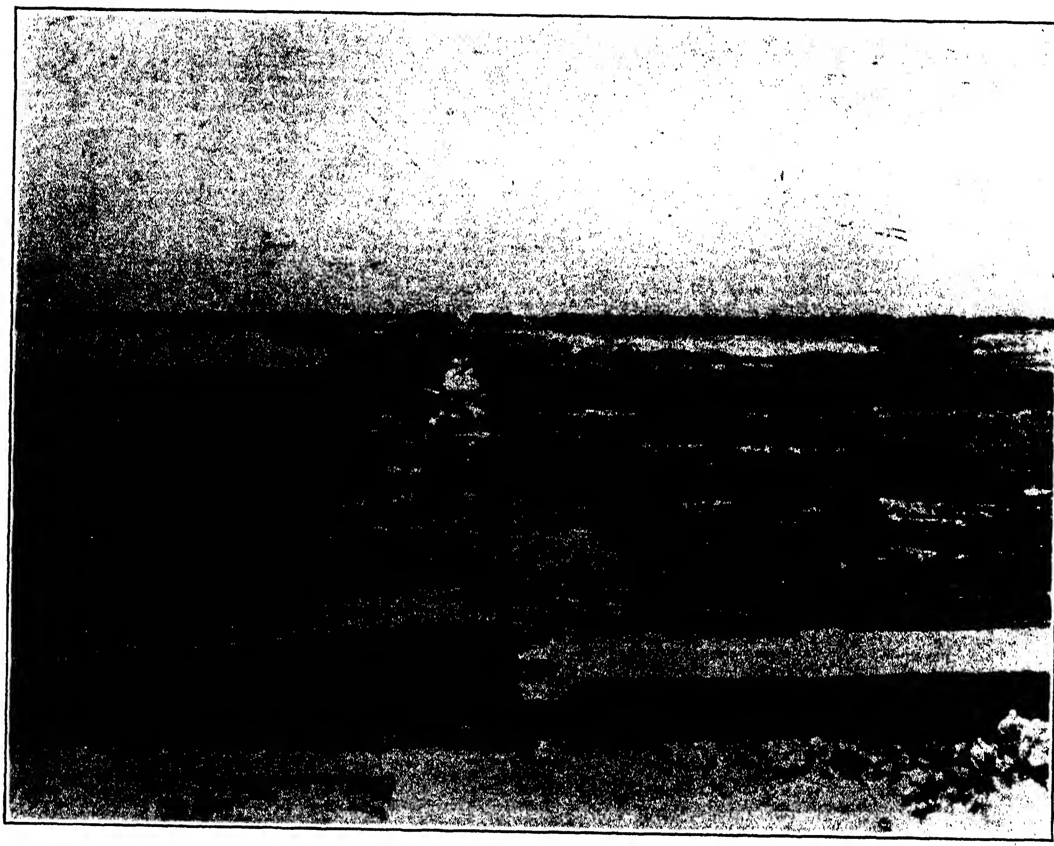


Fig. 17. Lafayette Dam, October 21, 1928.
Looking down the upstream face, showing buckling and overthrusting of the concrete facing.

Fig. 18. Lafayette Dam, October 21, 1928.
Upstream slope of dam, looking west.
Showing relatively slight movement of concrete facing.

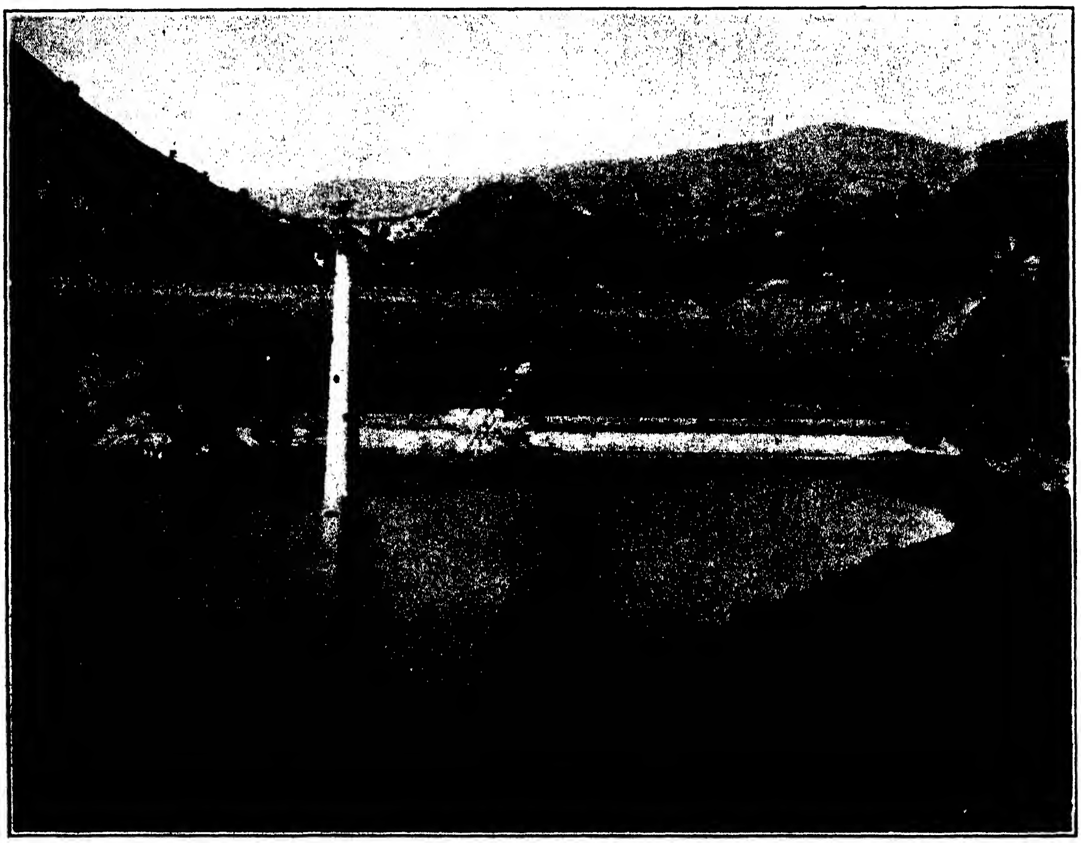


Fig. 19. Calaveras Dam—view before break.
Tower in foreground was carried upstream in upright position for 360 feet. It then toppled over and broke in three pieces (see Fig. 19A).

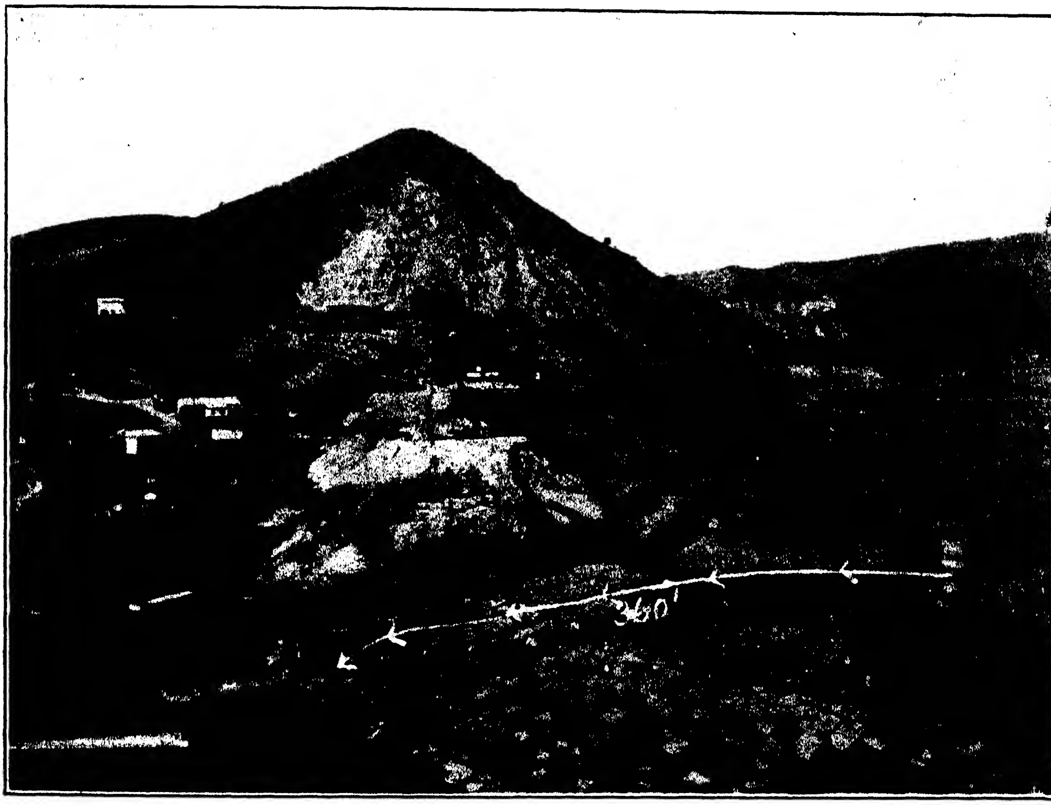


Fig. 19A. Calaveras Dam.
Showing location of tower after break. Earth dike at end of tower was placed afterwards in order to pump out section and recover gates. Caisson sunk through 50 ft. of slide, landed on tower foundation and connected with outlet tunnel to form temporary spillway which served during reconstruction.

Fig. 20. Calaveras Dam.
After the break. Note disappearance of tower and subsidence of upstream part of dam.
Downstream toe and beach remain intact.

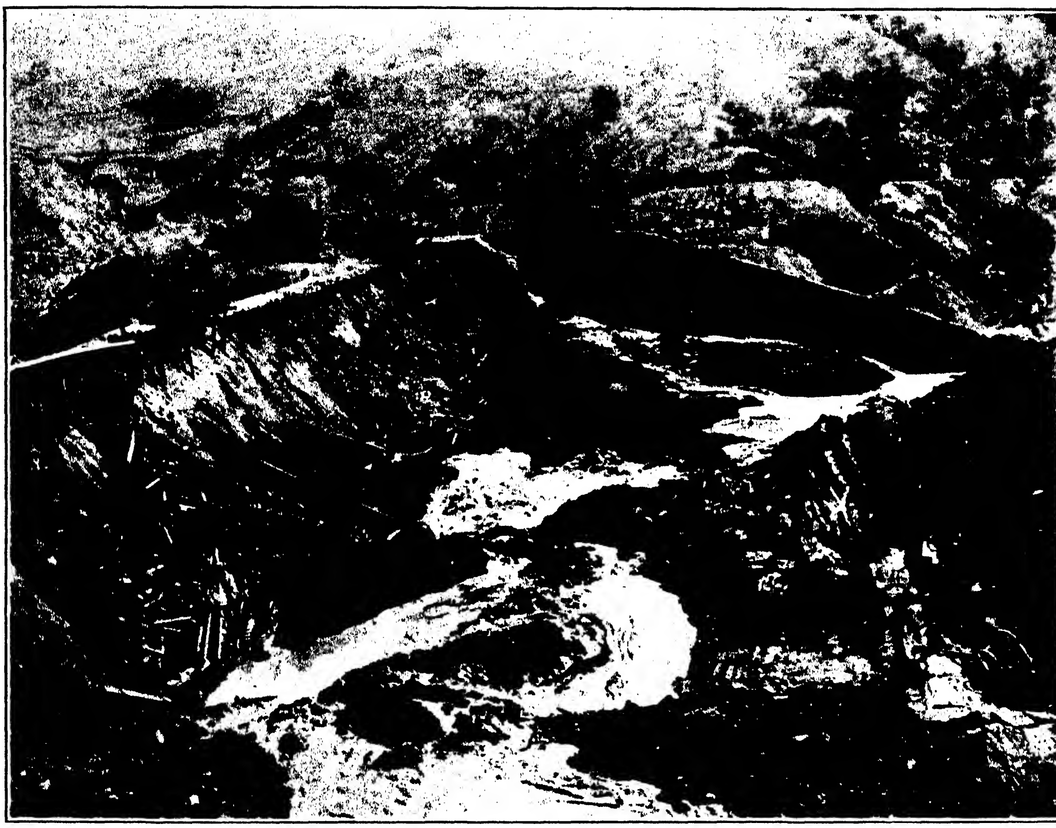


Fig. 21. Calaveras Dam.
A close-up of break.
Debris, trucks, timber and implements were carried into the pit.

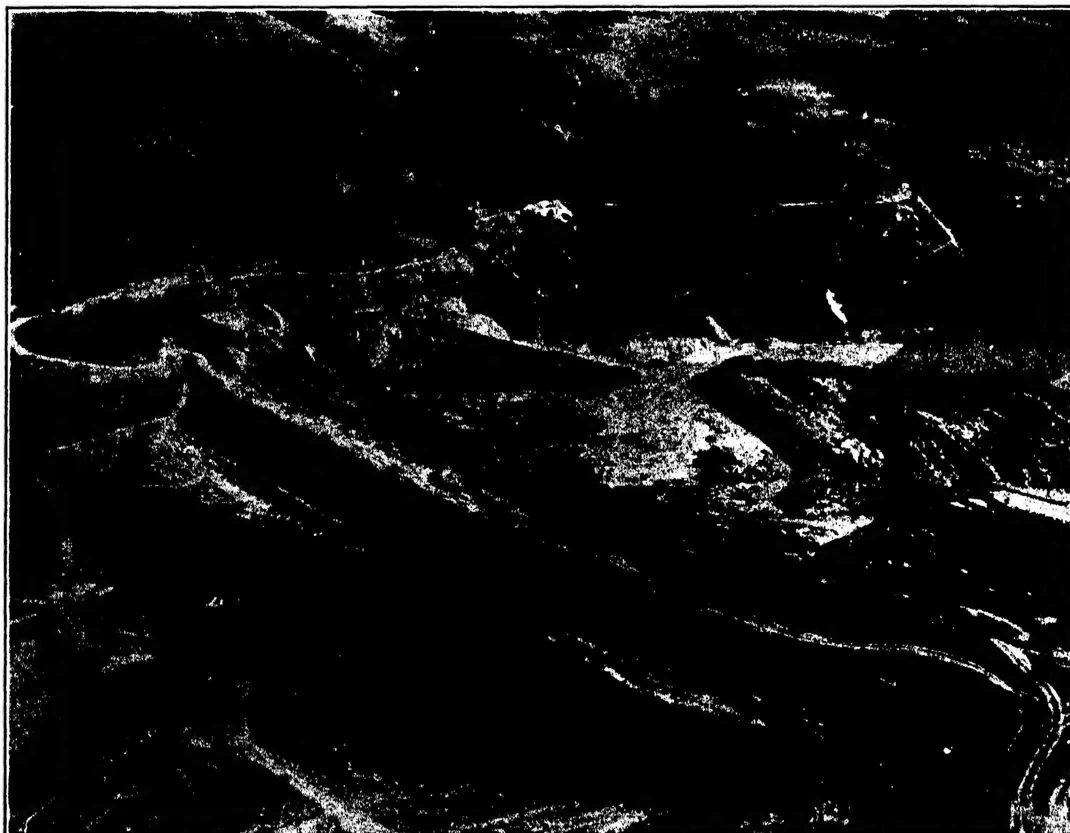


Fig. 22. Calaveras Dam.
Airplane view of break.
Showing relatively little damage to downstream face and berms.

Fig. 23. Calaveras Dam.
Portion of clay core trapped in the interior of dam.

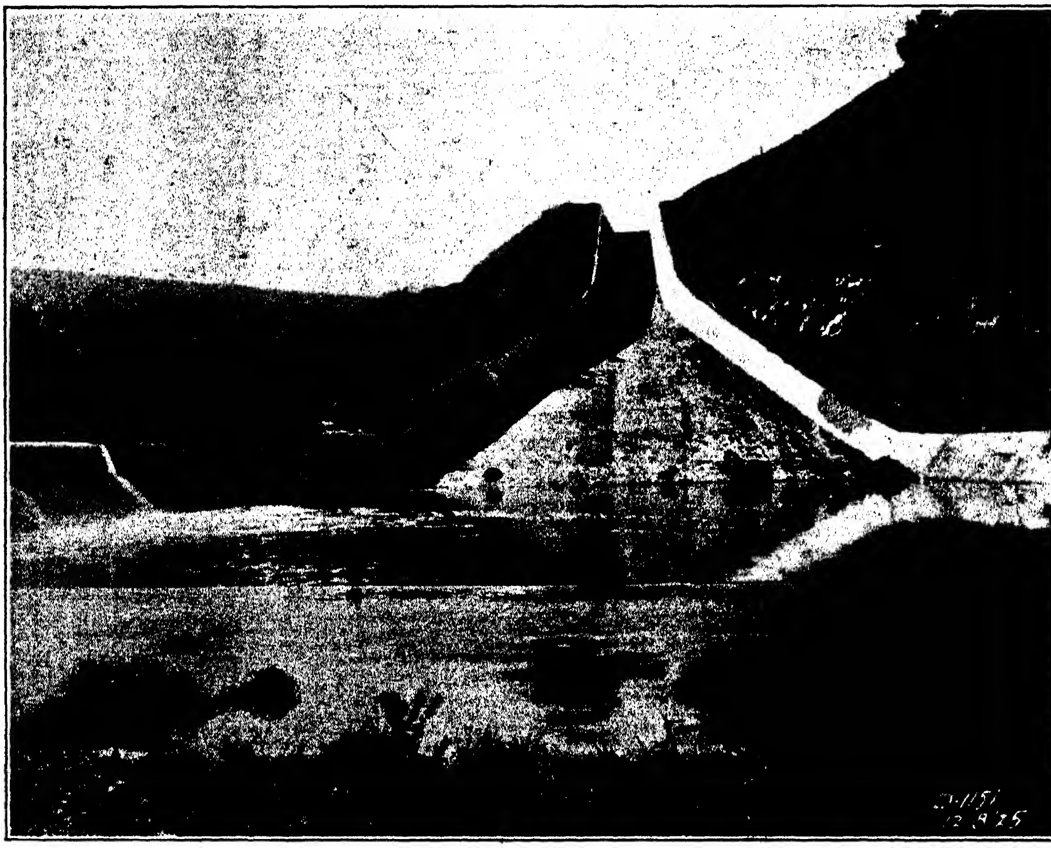


Fig. 24. Reconstructed Calaveras Dam.
A downstream view of the spillway.

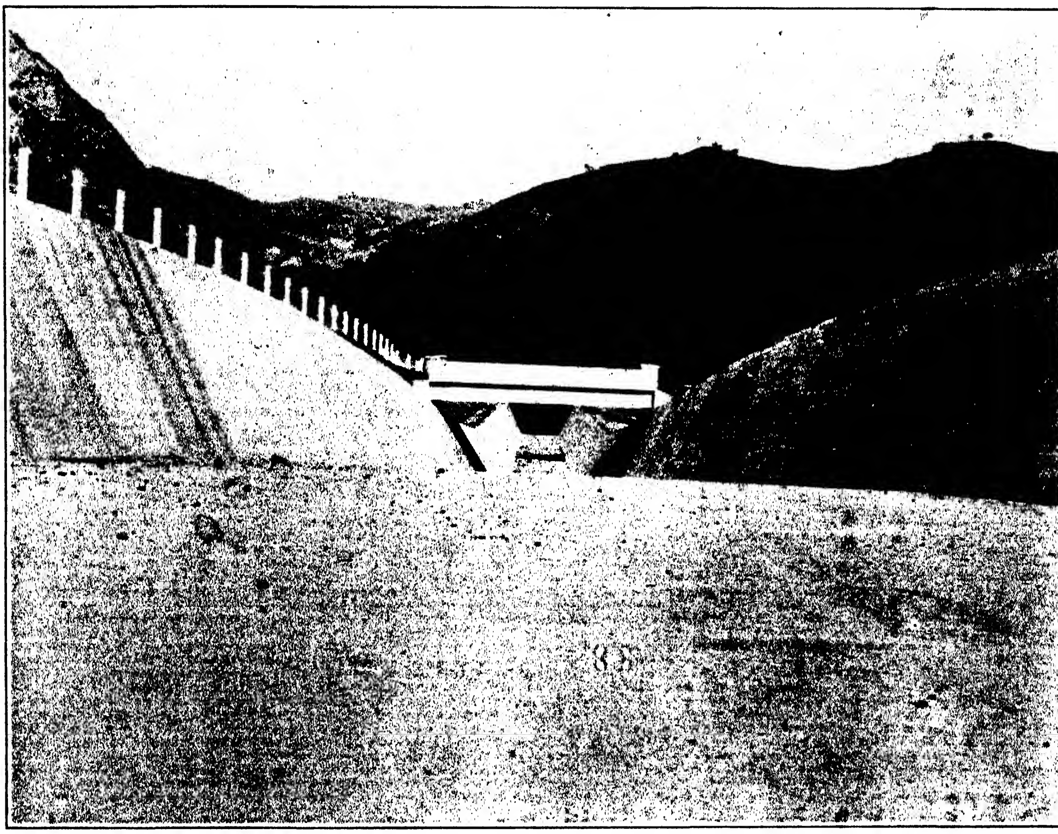


Fig. 25. Reconstructed Calaveras Dam.
View at spillway looking downstream from crest.

Fig. 26. Reconstructed Calaveras Dam.
Descriptive Tablet.

Fig. 27. Calaveras Dam.
Repair operations.
Hard stone riprap going into place.

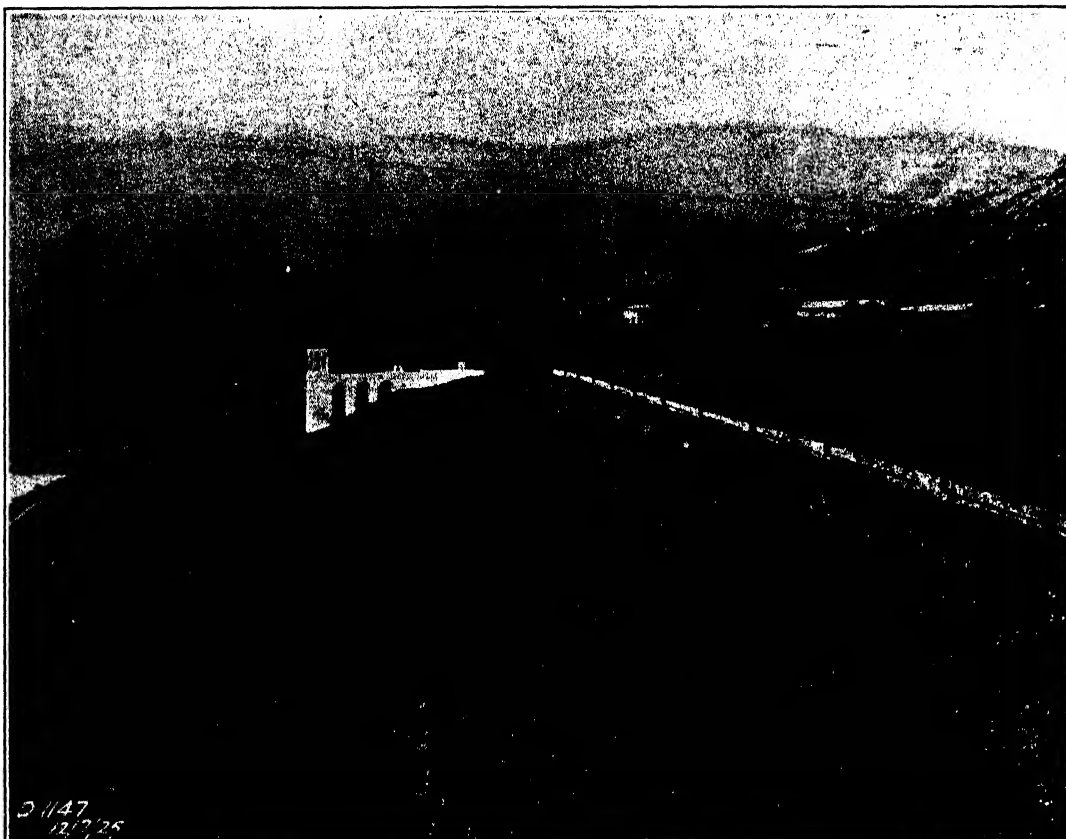


Fig. 28. Reconstructed Calaveras Dam.
Showing completed upstream face and berm.
New outlet tunnel and tower in background.

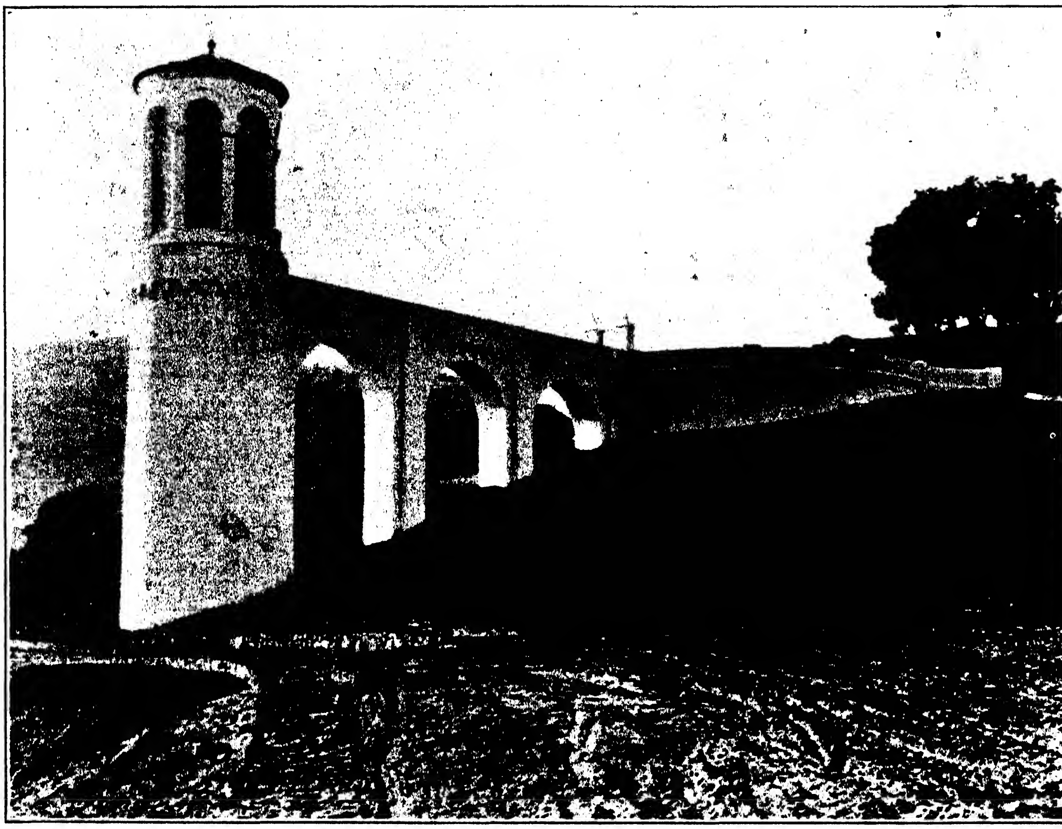


Fig. 29. Calaveras Dam.
View of new tower. December, 1925.

Fig. 30. Reconstructed Calaveras Dam, 1926.
A general view of downstream side of dam showing roads, berms, spillway, towers, etc.

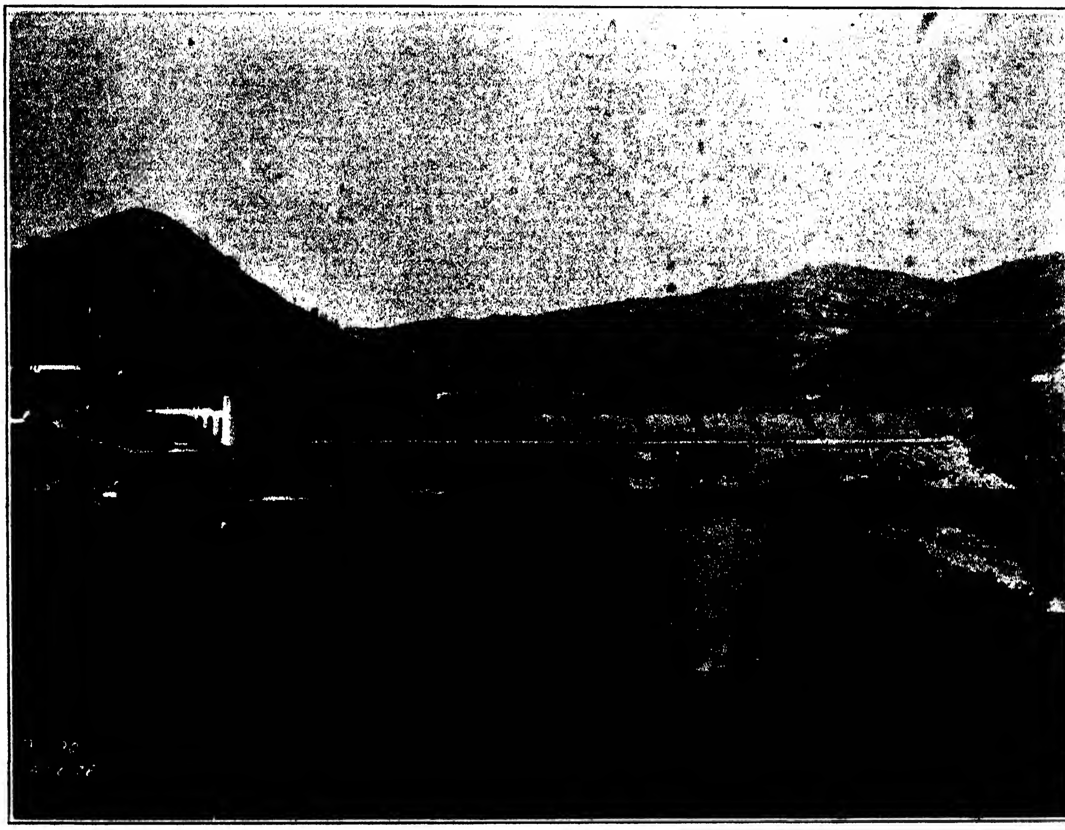


Fig. 31. Calaveras Dam in 1926.
A general view of the reconstructed dam with the reservoir in service.

Fig. 32. Calaveras Dam in December, 1925.
A downstream view of the dam in service.

The Fourth Pacific Science Congress

By R. H. Van Zwaluwenburg

The Fourth Pacific Science Congress convened in Java from May 16 to 25, 1929, the inaugural meeting being opened by His Excellency the Governor-General of the Netherlands-Indies, at Weltevreden, Batavia. The Congress was then transferred to the mountain city of Bandoeng, where the remaining sessions were held in the buildings of the Technical Faculty. The Congress was held under the auspices of the Netherlands-Indies Science Council, and was supported by the high patronage of the Netherlands-Indies Government. The first Pacific Science Congress was held in Honolulu in 1920, the second in Sydney in 1923, and the third in Tokyo in 1926.

The following officers presided over the activities of the Congress in Java: General President, Dr. O. de Vries, Director of the Rubber Experiment Station, Buitenzorg; General Vice-President, Dr. J. Clay, Professor of Physics at the Technical Faculty, Bandoeng; First General Secretary, Dr. H. J. Lam, Herbalist of the Botanical Gardens, Buitenzorg; Joint General Secretary, Dr. H. J. T. Bijlmer, Military Surgeon, Batavia; and Treasurer, Dr. H. M. Hirschfield, Java Bank, Batavia.

The chairmen of the three divisions under which the Congress functioned were: Division of Physical Sciences, Mr. A. C. de Jongh, Director of the Geological Survey, Bandoeng; Division of Biological Sciences, Dr. W. M. Docters van Leeuwen, Director, Botanical Gardens, Buitenzorg; and Division of Agricultural Sciences, Dr. J. J. B. Deuss, Director, Tea Experiment Station, Buitenzorg. The divisions were divided into the following sections:

Physical Sciences: astronomy, geography, geology, meteorology, oceanography, palaeontology, petrography, radio-telegraphy, seismology and volcanology.

Biological Sciences: anthropology, botany, ethnology, fisheries and zoology.

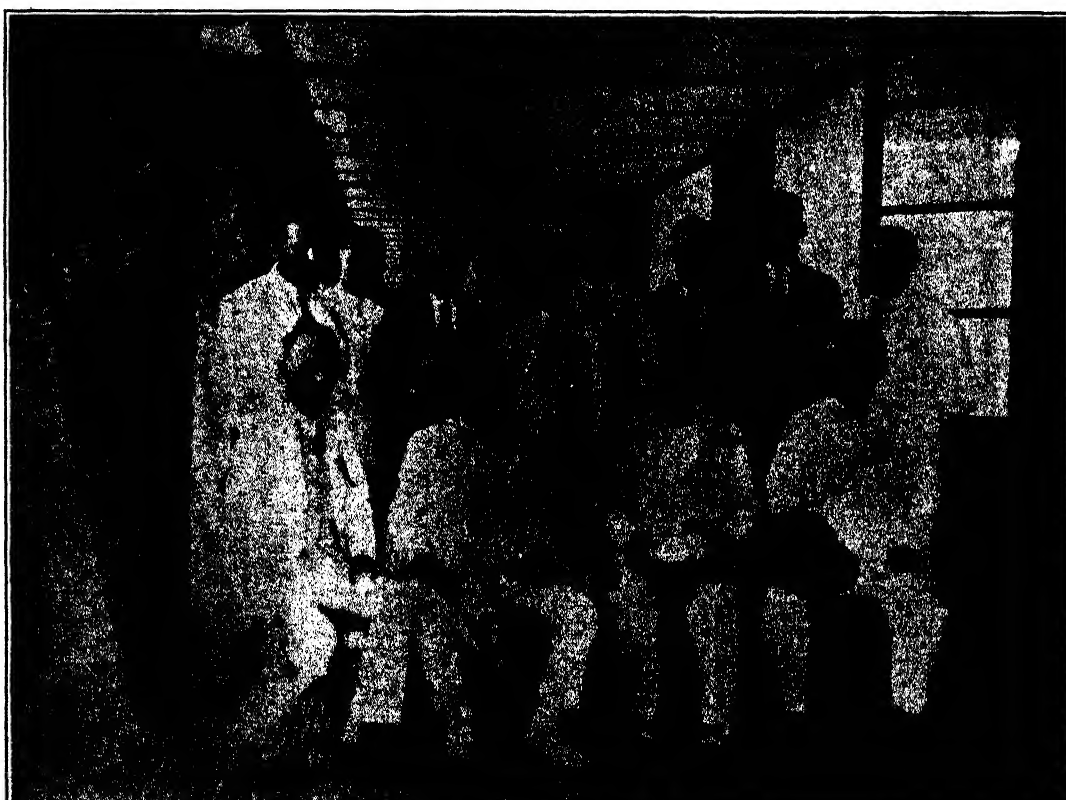
Agricultural Sciences: foresty, phytopathology and soil technology.

Over 250 delegates and participants attended the Congress from overseas, besides a large number of scientific workers from the Netherlands-Indies. Besides those named in the preceding paragraphs, delegates from the Netherlands East Indies were: Dr. J. Boerema, Director of the Royal Magnetic and Meteorological Observatory; Dr. K. W. Dammerman, Chief, Zoological Museum and Laboratory, Buitenzorg; Dr. H. C. Delsman, Director, Marine Biological Laboratory, Batavia; Dr. H. Gerth, Geological Survey, Bandoeng; Dr. W. F. Gisolf, Petrographer, Geological Survey, Bandoeng; Dr. G. van Iterson, President, General Agricultural Syndicate, Batavia; Dr. B. J. O. Schrieke, Professor of Ethnography at the Faculty of Law, Batavia; Dr. C. E. Stehn, Chief, Volcanological Survey, Bandoeng; Dr. P. van Stein Callenfels, Inspector, Archeological Service, Ngebel, Ponorogo; Dr. J. Stroomberg, Chief, Division of Commerce, Department of Agriculture, Industry and Commerce, Buitenzorg; Dr. J. H. F. Umbgrove, Geologist, Geological Survey, Bandoeng; Dr. J. Verwey, Zoologist, Marine Biological Laboratory, Batavia; Dr.

S. W. Visser, Sub-director, Royal Magnetic and Meteorological Observatory, Batavia; Dr. J. T. White, Chief, Pedölogical Institute of the General Agricultural Experiment Station, Buitenzorg; and Dr. R. Wind, Director, Forest Research Institute, Buitenzorg.

Among the delegates from Holland were Dr. L. F. de Beaufort, Director, Zoological Museum of the Royal Zoological Society, Amsterdam; Dr. H. A. Brouwer, Professor, University of Amsterdam; Dr. E. van Everdingen, Director, Royal Netherlands Meteorological Institute, De Bilt; Dr. J. Jeswiet, Professor of Plant Taxonomy, Academy of Agriculture, Wageningen; Lieutenant-Commander F. Pinke, Royal Netherlands Navy, Commander S. S. "Willebrord Snellius"; Jhr. Dr. A. Roell, Provincial Governor of North Holland; Dr. W. J. K. Roepke, Professor of Entomology, Academy of Agriculture, Wageningen; and Dr. F. A. F. C. Went, Professor of Botany, University of Utrecht.

The American delegation, headed by Dr. T. Wayland Vaughn, Director of the Scripps Institution of Oceanography, La Jolla, California, included Mr. George Arceneaux, Dr. Leo H. Baekeland, Dr. Frederick V. Coville, Dr. Andrew C. Lawson, Dr. R. D. Rands, Dr. Oswald Schreiner, Dr. W. A. Setchell, and Dr. Philip S. Smith. Dr. C. Montague Cooke, Jr., led the Hawaiian delegation. Those in attendance from Hawaii were Dr. and Mrs. C. Montague Cooke, Jr., and Dr. E. Christophersen from the Bishop Museum; Mr. and Mrs. E. M. Ehrhorn,



Phytopathology Section, Pacific Science Congress, Bandoeng, Java
Front row (left to right)*: Roepke, Matsumura, Ehrhorn, Kuwana. *Second row*: Karny, Hazelhoff, Leefmans, van der Goot, Uichanco, South, Hoffman, Van Zwaluwenburg, Ochse. *(Photo by Dr. Roepke.)

representing the Federal Horticultural Board; and Dr. A. J. Mangelsdorf and R. H. Van Zwaluwenburg from the Experiment Station, H. S. P. A.

Various excursions were arranged for the delegates, both before and during the period that the Congress had its headquarters at Weltevreden. Among these were field trips to Buitenzorg to inspect the famous Botanical Gardens, and to the numerous governmental and private scientific institutions located in that city.

An outstanding feature was the two-day excursion to Krakatau Island, lying between Java and Sumatra. This volcano exploded with terrific violence in August, 1883, covering the island with hot ashes and pumice stone to a depth of from 30 to 60 meters. Dutch scientists have paid particular attention to the reestablishment of plant and animal life on Krakatau since the catastrophe. Professor Docters van Leeuwen considers it probable that all plant life was destroyed by this convulsion of nature, and that all the present elements are derived from imported plants, spores and seeds. Verbeek visited the island two months after the eruption and found not a single plant; a year later he found only a few shoots of grass. Between 1908 and 1928 Dr. van Leeuwens found 276 plant species established. There is evidence that this increase has been very gradual, going hand in hand with the increasing suitability of the environment. He outlines the succession of plant occupation as follows: When the whole shore and the volcanic cone were bare, only such plants could grow which can survive on such exposed places. Then followed plants whose seeds and fruits were distributed by the agency of animals, and in the first place such sorts as are the first to come up on an open, secondary terrain. "One must take it, of course, that the seeds of all these plants were not brought in only when circumstances were favorable, but, rather, that they were being constantly carried in but could only strike root when the environment was favorable for their survival."

In discussing the problem of the fauna of Krakatau, Dr. K. W. Dammerman concludes:

1. There is every reason to believe that the fauna was totally destroyed in the eruption of 1883.

2. The sequence in which the different species have since populated the island is probably as follows: first detritus forms, next plant-eating species, and, finally, carnivorous and parasitic forms. This only means that the animals have established themselves in such consecutive order and not that they reached the island in that sequence.

3. The conditions on the island today, in respect of the fauna, are still not yet normal. Some animal groups, for example, winged forms like birds and insects, have probably reached 50 to 60 per cent of what may be regarded as the norm; the same is true of the soil fauna. Other groups, like the moss fauna, may be regarded as fairly normal already.

4. In the first place, creatures reached the island by air, either actively flying or passively transported by the wind; in the second place by sea, either swimming or carried along with driftwood or other flotsam; in the third place, by the agency of other animals or man. The last-named agency has played a very insignificant part in the case of Krakatau, while arrivals by air may be put down at about 90 per cent of the island's fauna today.

5. Whether it is animals from Java or Sumatra that have found a home on this island cannot generally be known. The great majority of the species now found on Krakatau are extremely common and very widely spread.

6. Since on the islands of the Krakatau group a few sub-species of one and the same species occur together, or species exist here under conditions that vary from the normal, it is not impossible that we shall be able to observe here the origin of peculiar sub-species or the varying of species.

The opening session of the division of agricultural sciences was devoted to a discussion of the rice problem around the Pacific. Papers were read on the following subjects: irrigation and drainage, manuring and selection of the rice plant; treatment of the rice crop and the harvest, soil management and tillage, and pests and diseases of the rice crop.

Dr. P. van der Goot of Buitenzorg contributed a paper on "Pests of the Rice Crop Around the Pacific," including a discussion of the most important enemies of the crop in the Dutch East Indies. There the white rice borer *Scirpophaga innotata* Walker ranks easily first as a pest. The crux of this problem is that the full-grown caterpillars of this borer remain dormant in the stubble after harvest; this period of "aestivation" takes at least 4 or 5 months and comes to an end only at the first showers at the beginning of the rainy season. The moths begin to emerge from the stubble four to six weeks after the first shower, and all of them have issued within the following two weeks. On these facts is based the very effective system which Dr. van der Goot has evolved for combating this pest in Java, which consists of the following procedure: (1) where possible and practical late sowing of the seed-beds, at least six weeks after the date of the first showers, is enforced, in order that all moths may have emerged from the stubble, and that later sowings therefore may remain free from infestation. (2) Where late sowing cannot be enforced, rice growers are *advised* about the proper date of transplanting the different varieties in such a way that the period of pre-flowering will not coincide with the emergence of the fourth generation of moths, and in this way serious damage may be evaded.

Other rice borers are considered by Dr. van der Goot to be of little importance in the Dutch East Indies. *Chilo simplex* (Butl.), which occurs also in Hawaii, is rather rare in Java, and Dr. van der Goot considers the egg-parasites, *Trichogramma australicum* Gir. and *T. minutum* Riley, to be the real agency holding *Chilo* in check. Numerous other rice pests, including the rice bug, *Leptocorisa acuta* Thunb., were discussed in this paper.

Dr. Inokichi Kuwana, of Tokyo, presented a paper on "The Rice Stem Borers in Japan." *Chilo simplex* and *Sesamia inferens* Walker are generally distributed throughout the Japanese Empire, the former having two generations annually, feeding upon many gramineous plants in addition to rice, and hibernating in the mature larval stage in the stubble. *Schoenobius incertellus* Walker is confined to Formosa and the southern islands of the Empire, has three generations a year, hibernates in the same stage as *C. simplex*, but confines itself to attacks on the rice plant. Dr. Kuwana listed two egg-parasites and about a dozen larval parasites, all Hymenoptera.

A second paper by Dr. Kuwana was "Important Insect Pests of the Rice

Crop in Japan," in which he discussed in detail the food plants, parasites, and artificial control of the three borers, *S. incertellus, C. simplex* and *Nonagria inferens* Walker. Other pests discussed in similar detail are a leafroller, *Parnara guttata* Brem., four important leafhoppers, and *Podops lurida* Brum., a moth whose larvae feed on the leaves and stem of the plant. Still another paper by the same author discussed the biology of *Trichogramma japonicum* Ashm. and *Phanurus beneficiens* (Zehnt), egg-parasites of the rice stem borers in Japan. In *Phanurus* parthenogenetic reproduction results in male progeny only, in Japan, but Dr. van der Goot stated that in Java this parasite produces only females parthenogenetically. (Since this was written it has been stated by a competent authority that the *Phanurus* of Japan is not *beneficiens,* but another, probably new, species.)

A fourth paper by Dr. Kuwana was entitled "Important Diseases of the Rice Crop in Japan." The most important are: (1) *Piricularia oryzae* Pri. and Car., which has three forms: leaf-blast, affecting young plants; rotten-node, damaging the sheath nodes just above the joints of the stems; and rotten-nick, affecting the stem where it forms the axis of the grain-head; (2) *Helminthosporium oryzae* B. de H.; (3) *Pseudomonas oryzae* Uyeda and Ishiyama; (4) *Hypochnus sasakii* Shir.

Dr. S. Nakayama, of Korea, presented a paper on "The More Important Insect Enemies of the Rice Crop in Chosen," listing ten important pests, including *Chilo simplex*, three species of leafhopper, an armyworm, two flea-beetles, and the grasshopper, *Oxya velox* Fab.

Dr. G. H. Corbett, of the Federated Malay States, submitted a paper, "Brief Notes on Some Padi Insects in Malaya," in which he discussed parasites of *Diatraea auricilia* Dudg. and two other stem borers, the habits and control of the rice bug *Leptocorisa acuta,* and notes on paddy bugs and leaf-feeding caterpillars.

Several other papers which will appear in the Proceedings of the Congress, but presentation of which was impossible due to lack of time, were also submitted. Among them were papers on rice diseases by Dr. C. M. Doyer, and by Dr. P. van der Elst of Java, and by Dr. R. Haskell, of the United States, and a summary of insects affecting rice in the Philippines, by Dr. L. B. Uichanco.

The second meeting of the division was devoted to papers dealing with the improvement of planting material in permanent crops. Prominent among these were: "Improvement of the Coconut Crop by Selection," by Dr. H. W. Jack, of Kuala Lumpur; "The Selection of Oilpalms," by Dr. J. F. Schmole; "The Selection of *Coffea arabica,*" by Dr. J. Schweizer; "The Selection of *Hevea* in Java," by Drs. O. de Vries, J. Schweizer and F. W. Ostendorff; and "The Restoration of the Louisiana Sugarcane Industry through the Adoption of Java Varieties of Cane," by Dr. R. D. Rands.

At the third session of the division, the section on phytopathology met separately. Although numerous papers on insect pests of important crops around the Pacific were submitted at this meeting, the entire time was given up to the discussion of international cooperation in insect control by means of natural enemies. This was based upon a paper by Dr. S. Leefmans, Director of the Institute for Plant Diseases at Buitenzorg, entitled "Cooperation in Parasite Work around the Pacific." In it he advocated the following aids to better cooperation in this important phase of entomology:

1. Interchange of lists of insect parasites and predators between workers in the countries around the Pacific.

2. Publication of full particulars of methods used in importing or sending useful insects from one country to another.

3. Better organization of the systematic side of parasitic work so as to facilitate speedier identification of material, particularly in the groups of parasitic Hymenoptera and Diptera. The majority of those present thought this could best be accomplished by grants of funds to museums which are already established, so as to permit the employment of additional systematists in the groups named.

4. Pushing of such scientific work on insects as is especially important for the further progress of applied entomology. This includes the further study of: the law of tropisms; the influence of climatic conditions; the influence of condition of plant hosts on their insect guests; the causes of monophagy and of polyphagy; the instincts and habits of insects; modes of insect dispersion and the influence of world traffic; relation between food and climate and biological races; the physiological relations between parasites and their hosts; the causes of monophagy and polyphagy in insect parasites; the causes of immunity of insects to parasite attack; the causes of aestivation, hibernation and migration; the causes of extreme multiplication of insects, etc.

As a result of this discussion, the Pacific Science Council presented a resolution, adopted in the final general meeting of the Congress, which provides for the formation of a standing committee on Pacific economic entomology. This committee will probably pay special attention to the points brought out in Dr. Leefman's excellent paper.

Among the twenty-eight resolutions adopted in final general session of the Congress were the following:

Recommendations that the International Code of Zoological Nomenclature be adopted by all workers on taxonomy of both extinct and living animals.

Recommendations for the establishment in the Malay Archipelago of an international marine biological and oceanographical station.

Recommendations for soil surveys and soil classification to be conducted on a uniform basis by all countries around the Pacific.

The Executive Committee announced the formation of a division of medical sciences. The invitation of the Canadian delegation to hold the Fifth Pacific Science Congress in Canada in 1932, was accepted unanimously. Following the closing business meeting, the President's dinner was held in Bandoeng on May 25, 1929.

There followed a week or more of field excursions planned to show the principal features of agriculture in Java, and the geology, zoology, botany, archeology, etc., of the country. One of these trips was to Trinil in eastern Java, where, in 1891, du Bois discovered the remains of the anthropoid, *Pithecanthropus erectus*, the prehistoric, so-called Java man. Another excursion was to the island of Bali, which lies to the east of Java, where an interesting Hindu civilization exists. Finally, on June 4 the Congress was brought to a close by a farewell banquet at Soerabaia.

Delegates Attending the Third Congress of the International Society of Sugar Cane Technologists, Java, 1929

By J. P. Martin

Delegates representing twelve sugar-producing countries of the world were present at the Third Congress of the International Society of Sugar Cane Technologists, which was held in Java, June 7 to 19, 1929.

The countries represented at the Congress are as follows: Australia, Egypt, Hawaii, Indo-China (French), British India, British West Indies, Japan and Formosa, Java, Mauritius, the Philippines, Porto Rico and the United States of America (continental).

The general and sectional meetings were held in Soerabaia, June 7 to 14, while the field excursions, which covered the main sugar-producing districts of Java, extended from June 14 to 19. The delegates were divided into two groups before starting on the field excursions: one group, under the leadership of Dr. V. J. Koningsberger, included the agriculturists, entomologists and pathologists; the other group, under the direction of Dr. E. C. von Pritzelwitz van der Horst, included the technologists, who were interested primarily in factory operation and chemical control.

On the evening of June 19, a farewell dinner was given the delegates at Bandoeng by the General Syndicate of Sugar Manufacturers in the Dutch East Indies.

During the meetings, the writer was able to secure the addresses of all delegates and, with the exception of three, a photograph of each delegate.

The object of this article is mainly to list the various delegates, under the name of the country they represented, with their addresses and photographs.

AUSTRALIA—

1. DR. A. J. GIBSON,
   Bingera Estate,
   Bundaberg, Queensland.
2. DR. H. T. EASTERBY,
   Director, Bureau of Sugar Experiment Stations,
   Brisbane, Queensland.
3. N. BENNETT,
   Sugar Technologist, Bureau of Sugar Experiment Stations,
   Brisbane, Queensland.

EGYPT—

4. P. NEUVILLE,
   Engineer, Raffinerie, Hawamdieh,
   Egypt.

HAWAII—

5. J. W. WALDRON,
   First Vice President, Hawaiian Sugar Planters' Association,
   Chairman, Experiment Station Committee, H.S.P.A.,
   Honolulu, T. H.
6. N. H. BAIRD,
   Theo. H. Davies & Co., Ltd.,
   Honolulu, T. H.
7. L. D. LARSEN,
   Manager, Kilauea Sugar Plantation Company,
   Kilauea, Kauai, T. H.
8. W. W. G. MOIR,
   Agricultural Technologist, American Factors, Ltd.,
   Honolulu, T. H.
9. W. L. McCLEERY,
   Associate Sugar Technologist, Experiment Station, H.S.P.A.,
   Honolulu, T. H.
10. R. A. HUTCHISON,
    Manager, Laupahoehoe Sugar Company,
    Papaaloa, Hawaii, T. H.
11. H. P. AGEE,
    Director, Experiment Station, H.S.P.A.,
    Honolulu, T. H.
12. U. K. DAS,
    Assistant Agriculturist, Experiment Station, H.S.P.A.,
    Honolulu, T. H.
13. W. VAN HEEMSKERCK DUKER,
    Consulting Chemist, Theo H. Davies & Co., F. A. Schaefer & Co.,
    Ltd., Hawi Mill & Plantation Co., Ltd.
    Honolulu, T. H.
14. DR. A. J. MANGELSDORF,
    Geneticist, Experiment Station, H.S.P.A.,
    Honolulu, T. H.
15. DR. GERTRUDE CASSIDY,
    Assistant Nematologist, Experiment Station, H.S.P.A.,
    Honolulu, T. H.
16. S. S. PECK,
    Manager, Technical Department, Alexander & Baldwin, Ltd.,
    Honolulu, T. H.
17. J. P. MARTIN,
    Pathologist, Experiment Station, H.S.P.A.,
    Honolulu, T. H.

INDO-CHINA (French)—

18. P. VIEILLARD,
Inspecteur des Services Agricoles,
Inspection Generale de l'Agriculture,
Hanoi, Indo-China.

BRITISH INDIA—

19. D. G. WALAWALKAR,
Chemist and Technologist,
Malvan, Bombay, India.

20. K. C. BANERJEE,
Secretary, Sugar Technologists' Association of India,
67 George Town, Allahabad, India.

12. U. K. DAS (see 12 above).

21. DR. T. S. VENKATRAMAN,
Government Sugar Cane Expert (Geneticist).
Imperial Sugar Cane Station,
Coimbatore, South India.

22. S. J. SABNIS,
Chemist, Burma Sugar Co., Ltd.,
Sahnaw, Upper Burma.

BRITISH WEST INDIES—

23. W. SCOTT,
Sugar Technologist, Imperial College of Tropical Agriculture,
Trinidad, B. W. I.

JAPAN and FORMOSA—

24. S. KUSAKADO,
Director and General Superintendent of Taiwan Seito Co.
(Formosa Sugar Manufacturing Co.)
Yuraku Bldg., Marunouchi, Tokyo, Japan.

25. DR. K. OSHIMA,
Professor, Imperial University of Formosa,
Taihoku, Formosa.

26. *MANABU SAWA,
Agriculturist, Niitaka Seito Kaisha,
Tairin, Kagi, Formosa.

27. *TOSHIO SAKAMOTO,
Geneticist, Shinkwa Sugar Experiment Station,
Shinkwa, Formosa.

JAVA—

28. DR. P. HONIG,
Director, Technological Department, Sugar Experiment Station,
Pasoeroean, Java.

29. *M. HOOLBOOM,
Consulting Engineer of Anemaet & Co.,
Soerabaia, Java.

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* Delegates not shown in the photographs.

30. DR. J. JESWIET,
Professor of Plant Taxonomy, Dendrology and Plant Geography,
College of Agriculture,
Wageningen, Holland.

31. DR. V. J. KONINGSBERGER,
Director, Agricultural Department, Sugar Experiment Station,
Pasoeroean, Java.

32. N. J. PEEREBOOM,
Consulting Agriculturist of Kooy & Company's Administratiekantoor,
Soerabaia, Java.

33. G. M. PERK,
Consulting Chemist of the Ned. Indische Landbouw Maatschappij,
Soerabaia, Java.

34. PROFESSOR E. C. von PRITZELWITZ van der HORST,
Director, Engineering Department, Sugar Experiment Station,
Pasoeroean, Java.

35. PROFESSOR F. A. F. C. WENT,
Professor of Botany,
Utrecht, Holland.

36. DR. G. WILBRINK,
Directress, Cheribon Sub-Experiment Station,
Cheribon, Java.

MAURITIUS—

37. LOUIS BAISSAC,
Technologist, Department of Agriculture,
Reduit, Mauritius.

PHILIPPINE ISLANDS—

38. ADDISON KINNEY,
Assistant Superintendent of Fabrication, San Carlos Milling Company, San Carlos, Occidental Negros,
Philippine Islands.

39. COLIN W. WADDELL,
Assistant of Fabrication, San Carlos Milling Company,
Occidental Negros, P. I.

40. G. STOWER,
Manager, La Carlota Central,
Occidental Negros, P. I.

41. JUAN O. CHIOCO,
Manila, P. I.

42. DR. MANUAL L. ROXAS,
Agricultural Technologist, Philippine Sugar Association,
Room 316, Roxas Bldg., Manila, P. I.

43. E. T. WESTLY,
Factory Superintendent, Del Carmen Central,
Del Carmen, Pampanga, P. I.

44. H. COSTENOBLE,
Chief Cane Inspector, Pampanga Sugar Mills,
Del Carmen, Pampanga, P. I.

45. L. B. UICHANCO,
Professor of Entomology,
College of Agriculture,
Laguna, P. I.

PORTO RICO—

46. R. FERNANDEZ-GARCIA,
Director, Insular Experiment Station,
Rio Piedras, Porto Rico.

47. M. A. DEL VALLE,
General Superintendent, Central Constancia,
Toa Baja, Porto Rico.

UNITED STATES of AMERICA—
(Continental)

48. DR. F. W. ZERBAN,
Chemist in Charge, New York Sugar Trade Laboratory,
80 South Street, New York City, N. Y.

49. GEORGE ARCENEAUX,
Agronomist in Charge, U. S. Sugar Plant Field Station,
Houma, Louisiana, U. S. A.

50. DR. OSWALD SCHREINER,
Chief, Division Soil Fertility, Bureau Chemistry and Soils,
U. S. Department of Agriculture,
Washington, D. C.

51. A. H. ROSENFELD,
Consulting Technologist, American Sugar Cane League,
1005 N. O. Bank Bldg.,
New Orleans, U. S. A.

52. DR. R. D. RANDS,
Senior Pathologist, Sugar Plants,
Bureau of Plant Industry, U. S. Department of Agriculture,
Washington, D. C.

The Executive Committee for the 1929 Congress was composed of the following members:

General Chairman......Dr. J. Jeswiet,
General Secretary......D. L. van Dine (absent from 1929 Congress),
Assistant Secretary.....Dr. V. J. Koningsberger.

The Executive Committee for the 1932 Congress, which is to be held in Porto Rico, is as follows:

General Chairman..........................Dr. F. W. Zerban
General Secretary..........................A. H. Rosenfeld,
Assistant Secretary........................Manuel A. del Valle.

Many Java members of the Society took a very active part in serving on com-

mittees and presenting papers at the meetings. These members aided greatly in making the Conference a success and their names are listed below, as published in the program of the Congress:

Java Members:

1. J. M. L. ALBERTI,
   Consulting Agriculturist Mij. tot Exploitatie
   der S. O. Sentanenlor c. s.
2. Jhr. W. ALEWIJN,
   Technologist, Sugar Experiment Station.
3. W. APPEL,
   Advies en Controlebureau Appel.
4. DR. J. P. BANNIER,
   Consulting Agriculturist Oei Tiong Ham Mills.
5. G. BENTHEM Az.,
   Technologist, Coster van Voorhout & Co.
6. G. BOOBERG,
   Actg. Vice-Director, Agr. Dep. of the Sugar Experiment Station.
7. J. H. BOON,
   Consulting Technologist, N. I. Landbouw Mij.
8. MISS DR. P. C. BOLLE,
   Phytopathologist, Cheribon Sub-experiment Station.
9. DR. G. BREMER,
   Cytologist, Sugar Experiment Station.
10. DR. R. BRINK,
    Agricultural Technologist, Sugar Experiment Station.
11. E. W. CLASON,
    Agricultural Technologist, Sugar Experiment Station.
12. DR. J. H. COERT,
    Agricultural Technologist, Sugar Experiment Station.
13. H. W. DANIELS,
    Agricultural Technologist, Sugar Experiment Station.
14. Ir. A. DELFOS,
    Consulting Technologist, Handelsvereeniging "Amsterdam".
15. E. DEMANDT,
    Inspector of Agriculture, Sugar Experiment Station.
16. DR. C. van DILLEWIJN,
    Agricultural Technologist, Sugar Experiment Station.
17. DR. K. DOUWES DEKKER,
    Chemist, Sugar Experiment Station.
18. Ir. J. van DIJK,
    Inspector of Agriculture, Sugar Experiment Station.
19. RAY D. ELLIOTT,
20. Q. A. D. EMMEN,
    Consulting Engineer, Oei Tiong Ham Mills.
21. DR. J. M. GEERTS,
    Consulting Agriculturist, Ned-Ind. Landbouw. Mij.

22. Ir. J. GRIBLING,
Consulting Technologist, Handelsvereeniging "Armsterdam".
23. DR. E. H. HAZELHOFF,
Entomologist, Sugar Experiment Station.
24. DR. P. C. HART,
Agricultural Technologist, Sugar Experiment Station.
25. Ir. J. J. W. den HAAN,
Technologist, Sugar Experiment Station.
26. Ir. W. A. HATTINK,
Consulting Engineer, Cultuur, Mij der Vorstenlanden.
27. ING I. HES,
Technologist, Sugar Experiment Station.
28. Ir. M. S. Th. HOLTZAPFFEL,
Consulting Engineer, "Internationale Crediet-en Hendelsvereeniging Rotterdam."
29. C. van HOLST PELLEKAAN,
Superintendent, Koloniale Bank.
30. DR. T. H. van den HONERT,
Physiologist, Sugar Experiment Station.
31. A. HOMBRINK,
Agent, Internationale Crediet-en Handelsvereeniging "Rotterdam".
32. C. P. E. HOOLHORST,
Engineering Agent, "Werkspoor".
33. G. L. HOVENKAMP,
Manager "Gempol-Mills".
34. J. P. F. HUESE,
Technologist, Handelsvereniging "Amsterdam."
35. H. HOUWING,
Agricultural Technologist, Sugar Experiment Station.
36. C. A. J. JOCHEMS,
Sub-agent, Internationale Crediet-en Handelsvereeniging "Rotterdam".
37. DR. V. KHAINOVSKY,
Chemist, Sugar Experiment Station.
38. E. A. KLAY,
Consulting Engineer, Mijtot Expl. der S. O. Sentanenlor c.s.
39. DR. W. J. C. KOOPER,
Consulting Agriculturist, Internationale Crediet-en Handelsvereeniging "Rotterdam".
40. Ir. L. G. LANGGUTH STEUERWALD,
Superintendent, Mangkoenegorosche-Zaken.
41. E. H. LAPRE,
42. Ir. G. W. P. LIETH,
Consulting Chemist, Internationale Crediet-en Handelsvereeniging "Rotterdam".

43. J. W. L. van LIGTEN,
Consulting Chemist, Anemaet & Co.
44. Ir. G. LOOS,
Consulting Chemist, Koloniale Bank.
45. W. D. B. H. MULDER,
Secretary, Sugar Experiment Station.
46. Ir. W. J. M. MICHIELSEN,
Consulting Technologist, Handelsvereeniging "Amsterdam".
47. E. MOOYAART,
Consulting Technologist, Handelsvereeniging "Amsterdam."
48. DR. M. G. MULLER,
Consulting Agriculturist, Koloniale Bank.
49. P. MESSCHAERT.
50. Ir. F. Ls. MEYJES,
General Manager, Bergmann Electric Works, Ltd.
51. MISS Ir. G. A. NEEB,
Technologist, Sugar Experiment Station.
52. Ir. G. E. van NES,
Consulting Chemist, Oei Tiong Ham Mills.
53. P. C. NICOLA,
Technologist, Sugar Experiment Station.
54. DR. A. NIESCHULZ,
Agricultural Technologist, Sugar Experiment Station.
55. Chr. H. NIELSEN,
Consulting Technologist, Handelsvereeniging "Amsterdam".
56. DR. J. E. QUINTUS BOSZ,
Director, Simpang-Apotheek.
57. DR. E. F. V. RAABE,
Consulting Chemist, Mij. tot Exploitatie der S. O. Sentanenlor cs.
58. DR. A. RADERMACHER,
Agricultural Technologist, Sugar Experiment Station.
59. H. J. RODBARD,
Superintendent, Sugar-mills.
60. DRS. C. L. RUMKE,
Botanist, Sugar Experiment Station.
61. DRS. R. F. H. SCHMIDT,
Consulting Chemist, Cult. Mij. der Vorstenlanden.
62. Ir. G. J. SCHOTT,
Technologist, Sugar Experiment Station.
63. F. SIEWERTS van REESEMA,
Consulting Agriculturist, Cult. Mij. der Vorstenlanden.
64. Ir. W. A. SNELL,
Irrigation Adviser, N. I. Landbouw Mij.
65. DR. J. BARON van SLINGELANDT,
Director, Tiedeman en Van Kerchem.

66. P. E. STAVERMAN,
    Agent-in-Chief, Koloniale Bank.
67. C. SYLMANS,
    Technologist, Sugar Experiment Station.
68. Ir. H. J. SPOELSTRA,
    Technologist, Sugar Experiment Station.
69. DR. J. G. THIEME,
    Technologist, Handelsvereeniging, "Amsterdam".
70. Ir. L. D. TEUTELINK,
    Technologist, Sugar Experiment Station.
71. Ir. C. J. TONJES,
    Consulting Engineer, Koloniale Bank.
72. W. THOMSON,
    Technologist, Sugar Experiment Station.
73. Ir. A. G. WETHMAR,
    Agricultural Technologist, Sugar Experiment Station.
74. Ir. J. A. ZANDVELD,
    Technisch Bureau J. en C. Vrins.
75. ING H. GERBER,
    Irrigation Consulting Technologist Ned. Handel Mij.
76. J. U. F. BENZ,
    Treasurer, "General Sugar Organizations".
77. Ir. J. F. BOGTSTRA,
    Chemist, Sugar Experiment Station.
78. M. G. MOUT,
    Manager, "Watoetoelis-Mills".
79. H. Z. ZEGERS DE BEIJL,
    Manager, "Krian-Mills".

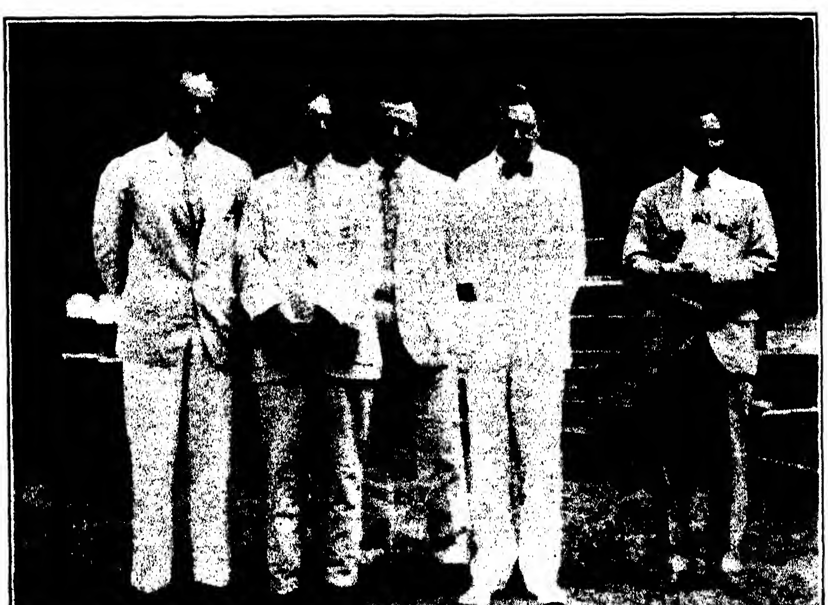
1 Gibson 2 Easterby 3 Bennett

4 Neuville

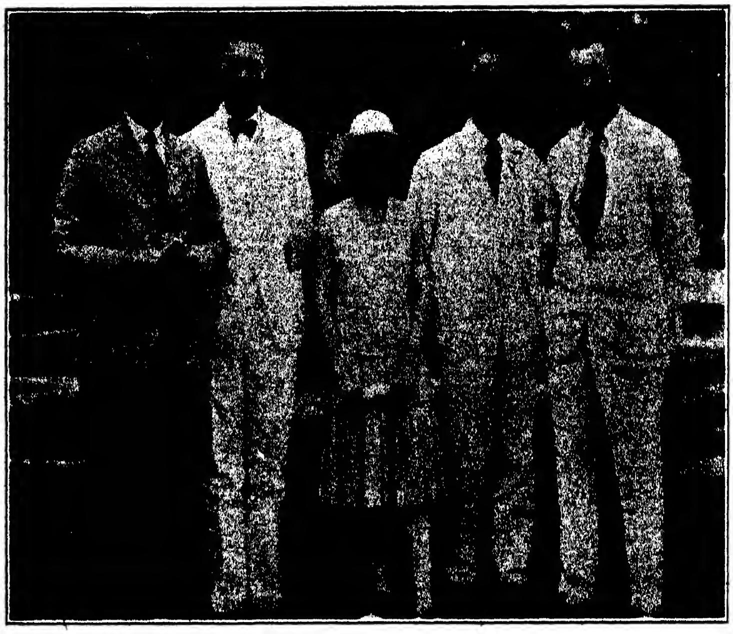
5 Waldron

6
Baird

7
Larsen



8 Moir | 9 McCleery | 10 Hutchison | 11 Agee | 12 Das



13 Duker, 14 Mangelsdorf, 15 Cassidy, 16 Peck, 17 Martin

18 Vieillard

19 Walawalkar, 20 Banerjee, 12 Das, 21 Venkatraman, 22 Sabnis

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Scott

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Kusakado

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Oshima

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Honig

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Jeswiet

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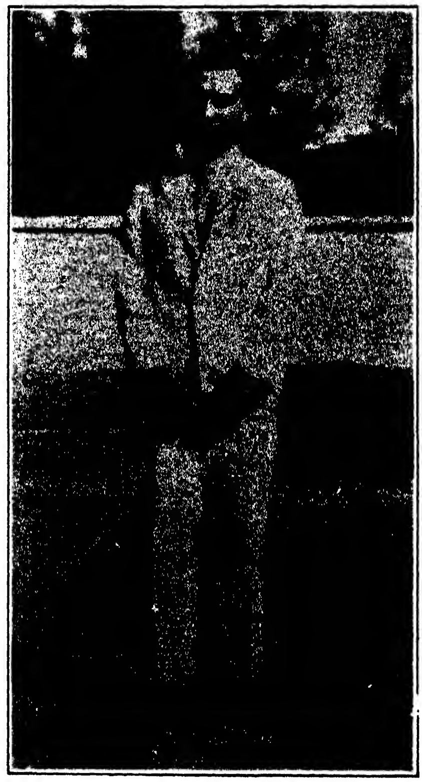
Koningsberger



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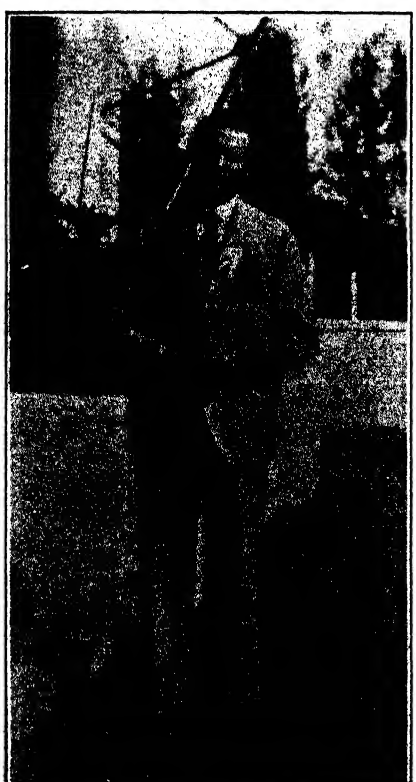
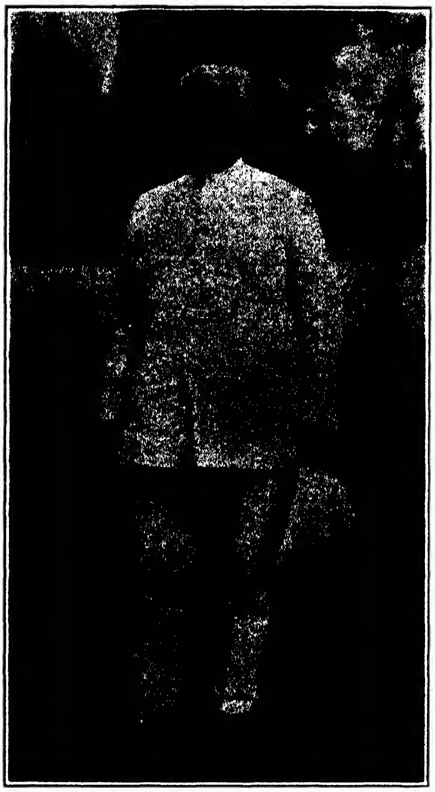
Peereboom



33
Perk

34
von Pritzelwitz van der Horst

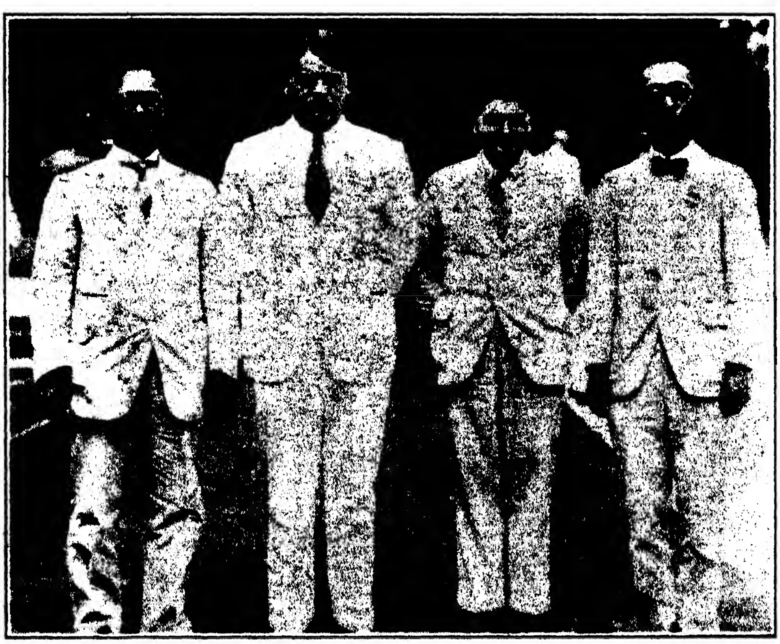


35
Went

36
Wilbrink

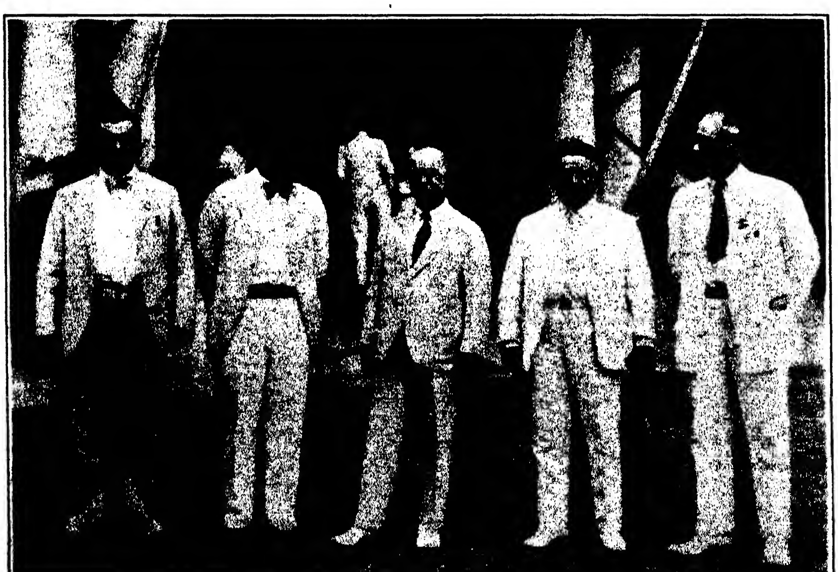
37
Baissac

38 Kinney | 39 Waddell | 40 Stower | 41 Chioco



42 Roxas | 43 Westly | 44 Costenoble | 45 Uichanco

46 Fernandez-Garcia   47 del Valle



48 Zerban   49 Arceneaux   50 Schreiner   51 Rosenfeld   52 Rands

Executive Committee—1929
Jeswiet Koningsberger

Executive Committee—1932
Rosenfeld del Valle Zerban

Sugar Prices

96° Centrifugals for the Period June 18, 1929, to September 15, 1929.

Date		Per Pound	Per Ton	Remarks
June	18, 1929	3.58¢	$71.60	Porto Ricos.
"	20	3.52	70.40	Cubas.
"	24	3.58	71.60	Cubas.
"	28	3.64	72.80	Cubas.
July	2	3.71	74.20	Cubas.
"	8	3.83	76.60	Cubas.
"	9	3.815	76.30	Cubas, 3.83; Philippines, 3.80.
"	10	3.77	75.40	
"	11	3.83	76.60	Philippines.
"	12	3.86	77.20	Cubas.
"	15	3.89	77.80	Cubas.
"	18	3.99	79.80	Cubas, 4.02; Porto Ricos, 3.96.
"	19	4.02	80.40	Cubas.
"	22	4.05	81.00	Philippines, 4.08; Porto Ricos, 4.02.
"	23	4.02	80.40	Porto Ricos.
"	24	3.975	79.50	Porto Ricos, 3.96; Cubas, 3.99.
"	25	3.89	77.80	Philippines.
Aug.	7	3.83	76.60	Cubas.
"	8	3.77	75.40	Porto Ricos.
"	16	3.83	76.60	Porto Ricos.
"	21	3.77	75.40	Philippines.
"	27	3.83	76.60	Porto Ricos.
"	28	3.815	76.30	Cubas, 3.83, 3.80.
Sept.	4	3.89	77.80	Porto Ricos.
"	9	3.99	79.80	Philippines, 3.96, 4.02.
"	10	4.02	80.40	Philippines.